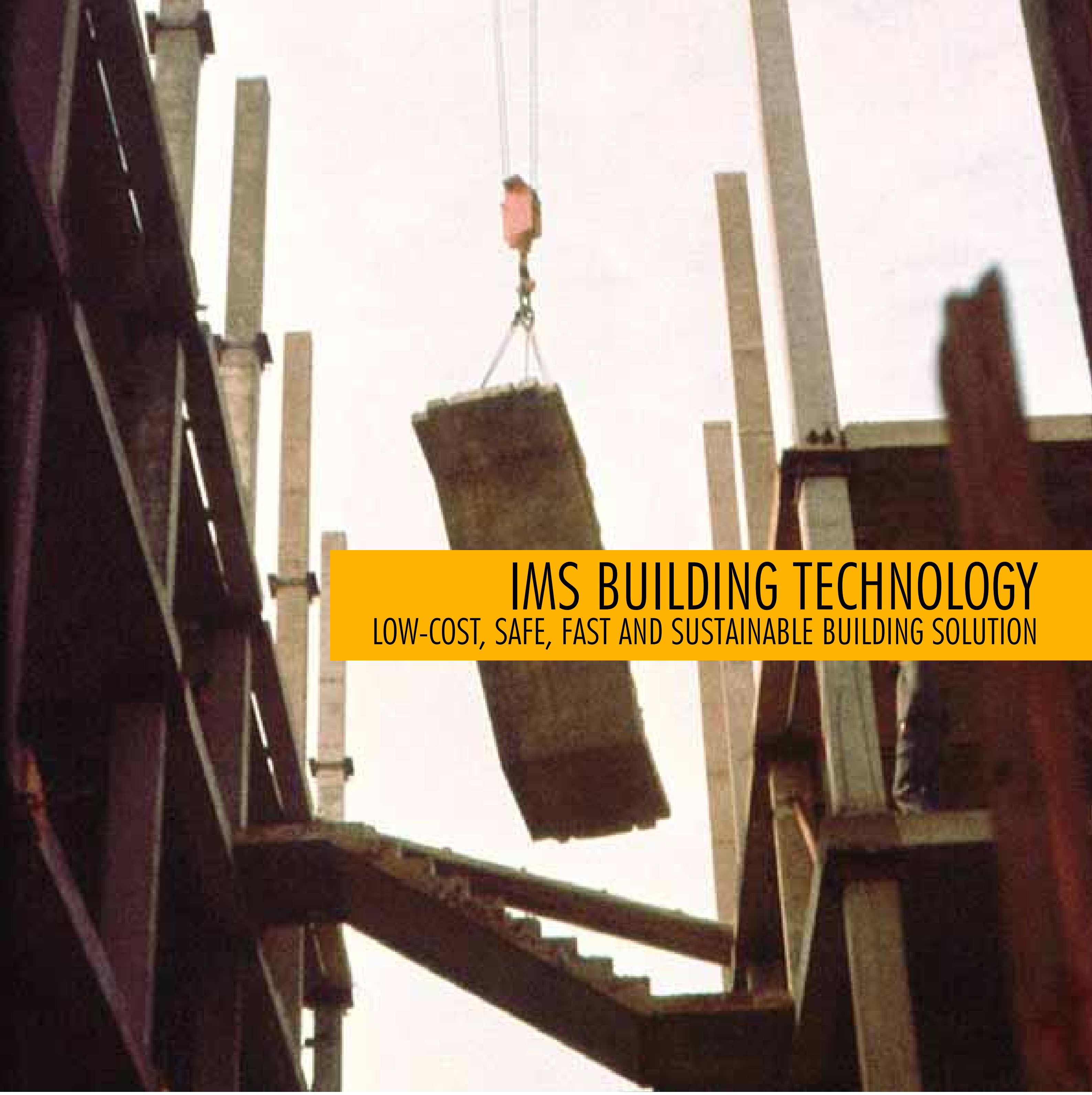


IMS BUILDING TECHNOLOGY

LOW-COST, SAFE, FAST AND SUSTAINABLE BUILDING SOLUTION

IDeass

SERBIA AND MONTENEGRO

Innovation for Development and South-South Cooperation

www.ideassonline.org

Presentation

Edited by Goran Petrovic, B. Sc. Architect

IMS Building Technology is an advanced system for accelerated construction with prefabricated elements of the skeleton.

This unique system based on the prestressed connection of the structure elements was developed by prof. Branko Zezelj at the IMS Institute in Belgrade. It was first implemented in 1957 and is since constantly being upgraded. The idea was simple – to build standard buildings by use of standard elements, as children do with Lego bricks. The toughest problem – the connecting of the elements of the concrete frame, made of prefabricated columns and slabs, was resolved through the application of steel cables aimed for the post-tensioning process. It is a revolutionary idea that required numerous researches and proofs, first of all, in the field of durability and stability and the in the field of architectural design and possibilities to be justified in practice as a universal technology for all kinds of high-rise structures.

IMS Building Technology is used for virtually any type of buildings: residential, schools, hospitals, houses, offices, light industrial edifices and various other.

IMS Building Technology has four main advantages:

- **Low-cost:** Significantly reduces building costs and accelerates investment turn over time; Minimizes the use of concrete and steel; Increases building durability; Is an high return investment; Does not require high-tech equipment.
- **Safe:** Prestressed structure dissipates kinetic energy caused by seismic activity or hurricanes and resists to earthquakes up to 9 degrees of Richter's scale.
- **Fast:** Accelerates building and diminishes construction time; Prefabricated elements can be produced in any season, weather or climate.
- **Sustainable:** Local materials or procedures can be applied on façades, roofing and interior surfaces, in order to obtain sustainable, energy-efficient and cost-efficient housing; Local human resources can easily be trained both to produce elements and carry out the building construction; Enables flexible solutions, greater space-planning capabilities and wide range of possibilities for building interior design.

IMS Building Technology enables extraordinary architectural solutions, increased technical performance and efficient organization. Numerous buildings and element production facilities have been built – more than 150.000 apartments in former Yugoslavia, Italy, Angola, Bulgaria, Egypt, Ethiopia, China, Cuba, Georgia, Hungary, Philippines, Russia and Ukraine.

Prefabricated prestressed skeleton has been tested in theory and experimentally, under all kinds of possible loads (static, dynamic, seismic, impact, fire) and it always showed, without exception, high safety coefficients. Verification and attesting of elements, joints and structure, as a whole, have been realized worldwide, and the research results are verified on numerous international congresses of specialized experts and scientific organizations.

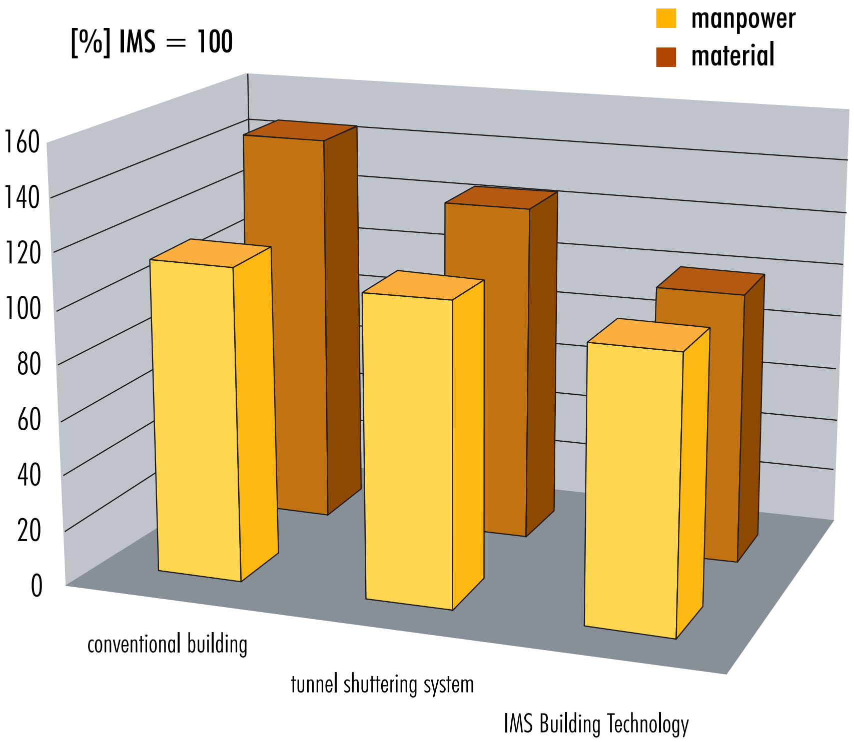
The IMS system holds the certificates of various institutions worldwide, such as: Ministry of Public Works, Italy, Ministry of Construction, Cuba, TbilZNIIEP Institute, Georgia, EMI, Hungary, Central Scientific – Research and design – Experimental Institute for the Construction of Complex Building Structures, Russia, Building Research Institute, Ministry of Construction, China.

How does IMS solve the building construction problem?

In the early 1950's, former Yugoslavia had a great problem of housing space deficit, which represented a challenge for the great constructor Branko Zezelj and his team, first of all the engineer Bosko Petrovic, with whom he developed and applied, at the time, a new building material – prestressed concrete. Designing bridges and halls unique in the world, he got a great idea to apply the material and technology of prestressed concrete in the field of building houses.

The prefabricated concrete frame consists of columns, beams, floors slabs, shear walls and staircases. It offers a wide variety of different buildings produced out of relatively small number of typical elements, precasted industrially in large series. An important characteristic of the IMS Building Technology is that it represents an open system, which can accommodate various subsystems, differing in both technology and materials.

During its 50 years of application all around the World, locations, where the buildings were constructed, were unfortunately exposed to natural and other catastrophes: earthquakes up to 8 Richter degrees (Banja Luka, Bosnia & Herzegovina), hurricanes (Havana and Cienfuegos in Cuba and Manila, Philippines), wars, bombings (Sarajevo, Mostar, Bosnia & Herzegovina, Osijek, Croatia), fires, accidents. In all those conditions buildings with prefabricated prestressed skeleton remained stable, as a whole, without significant damages, so that, after cosmetic remedial works, they are now in use again.



Cost indices per m² for different building systems

LOW-COST

The cost of IMS superstructure is relatively low. The reasons are various: first of all, this is an industrialized system, all structural components are studied theoretically, by full scale tests and in course of many years of practical application – low consumption of materials is fully justified; second, steel moulds can be applied hundreds of times, IMS assembly equipment makes the use of expensive timber negligible; third, IMS Building Technology is de facto not sensitive to rainy seasons and typhoons – minimum precaution measures can practically neutralize negative impact of these; fourth, IMS superstructure construction is fast and the progress is fully controllable.

SAFE

IMS system is a unique technical solution, providing fully integrated structural framework composed of the pre-cast elements and assembled by post-tensioning. All joints have the capacities that are at least equal to the capacities of the joined member sections; specific application of post-tensioning, theoretically studied and experimentally proved joints and appropriate assembly technology secure this. No weak joints take place and the assembled pre-cast post-tensioned framework superstructure acts as a fully integral structural system. In course of almost 50 years of the worldwide application, no cases of structural failure have been recorded.

In design of the IMS system, provisions of Unified Building Code (USA) are respected. 100% of designed seismic forces are transferred to the entire structure including shear walls. In addition to this, according to the requirements of mentioned Codes, structural frame (columns and floor elements, without participation of shear walls) is designed to accept 25% of seismic forces. IMS system complies also with Russian and other seismic codes.

STAGE	T_i	ΔT		ΔT	T_f
Initial		T_0			
IMS Pre-cast					
IMS Assembly					
Finishes					

Simplified construction schedule

FAST

The construction period of an entire project may be considered as shown in the simplified diagram presented below. Initial stage duration (Ti) depends on a variety of conditions that are not directly related to IMS technology (such as the type of foundations). However, it is assumed that IMS moulds and assembly equipment should be completed in course of this period. Finishes and services can start parallel with the IMS system assembly, but completion of these is not directly related to IMS technology. Thus, the period T_0 and time shift ΔT (see diagram below) define speed of construction of IMS System superstructure.

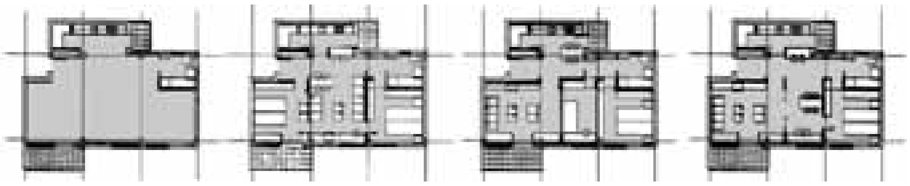
Complex architecture such as the one typical for prestigious condominiums, offices or hotels, requires many different types of pre-cast elements. This results in increased quantity of moulds needed for application of IMS Building Technology. Simple architecture, such as the one typical for low cost housing projects, schools or health centres, require a relatively small number of different types of pre-cast elements. This results in reduced quantity of moulds needed for application of IMS Building Technology. However, the complexity of architecture does not essentially influence the cost of superstructure construction.

SUSTAINABLE

The question that is frequently raised by potential users of industrialized technology is the extent of initial investments and impact of these on the project money flow schedule. The IMS industrialized building technology falls into the category of these requiring relatively small initial investments. The range of these investments has been proven during decades of experience with the application of the IMS Building Technology.

Common advanced payment of some 15% to 20% of the contract cost is sufficient for contractor to finish the project without negative balance in course of construction and to achieve the anticipated profit.

The simplicity of manufacture and its adaptability to a large range of conditions makes the system widely acceptable. It can be adapted to different grades of workforce skill, different levels of development of the construction technology and even to specific local conditions in regard to the availability of materials and products. The fact that the choice, method and timing of finishing works on the building can be left to the user makes the IMS Building Technology suitable for application in the construction of large housing estates. It enables the design of flexible apartments and other buildings, making it easier for the end user to participate in the process of creating his home.



Examples of spatial flexibility

IMS Building Technology, in practice

IMS Building Technology is based on reinforced concrete prefabricated skeleton, composed of basic reinforced concrete elements of the IMS system.

PRODUCTION OF ELEMENTS

The flexibility and adaptability of the IMS Building Technology to local conditions is obvious in the organisation of the production section of the IMS system basic elements. As steel moulds - the essential production equipment, are portable, element manufacturing can be organised in permanent plants, protected from atmospheric influences or in polygonal sections at the building site or at other locations near the site.

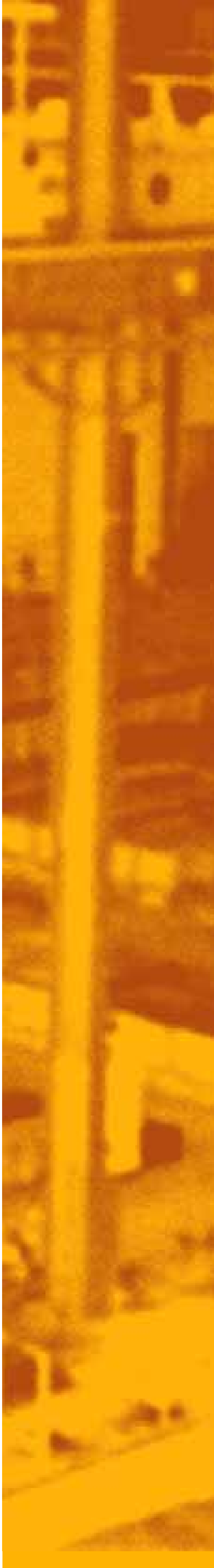
An average construction company already has the majority of the equipment required for the production and assembly of IMS system elements.

Permanent plants use appropriate bridge cranes, concrete plants, common equipment for concrete deposition (poker vibrators, external vibrators, vibrating plates), reinforcing sections with adequate equipment for straightening, cutting and rebar and assembly shaping, steam boiler room for steam curing of freshly set in concrete elements, workshops for equipment maintenance and the laboratory for quality control of the concrete.

Production at the polygon (open-air) enables various variants of section organisation depending on climate and other conditions; absolutely adequate to permanent plant in enclosed space; using tower cranes instead of the bridge ones; supply of concrete with transit mixers from concrete plants; protection from direct drying (instead of steam curing) of freshly set in concrete elements with plastic foils (if climate conditions allow).

Plant capacity is the most significant factor for the application rationality of the IMS Building Technology. Experience shows that minimal investment expenses in specific equipment for the IMS Building Technology are obtained for sections with annual production of 20,000 to 50,000 square meters of building structures. In that case, annual production absolutely depreciates investments in the equipment, while the same equipment is valuable per several years' production (8-10 years and more). Permanent plants are built, as well, for 100,000 m2 but those capacities require a complex organisation and building control and advanced training of human resources.

Quality control of building material and production process is necessary for element production and building stability and security during assemblage, erection and utilisation.



TRANSPORT

Transport of elements from the production plant to the site requires only common vehicles. The heaviest elements do not overpass 7 tones, and their dimensions enable the use of trucks in public traffic. Rational truck transportation radius is cca. 100 km, while in practice rationality of the boat transport is cca. 1,000 km. Elements can also be transported by railroad.

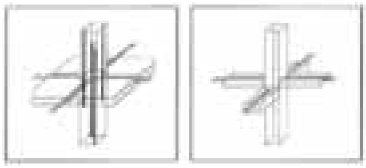
SKELETON ASSEMBLY

When building foundations are done, with precisely left openings for anchors of prefabricated columns, multi-storey columns are positioned and fixed, with the help of braces, in vertical position and controlled with geodetic surveying instruments (verticality and axis position). Temporary capitels already exists on columns on which floor structure elements are erected – floor slabs, edge beams and cantilever floor slabs. Afterwards, floor slabs are made monolith with web post-tensioning using appropriate short cables. Joints between columns and floor slabs are filled in with adequate mortar and, after its hardening, the entire floor plane is post-tensioned with cables into two orthogonal directions. After this action, braces fixing columns are released, supporting capitels are transported to another storey level and the operation of floor slabs erection is repeated.

Appropriate available cranes or auto-elevators are used for construction, in number and yield depending on building size and location. A well-organized group of 5 to 6 workers and a crane-operator can weekly complete a storey level of about 600 – 1,000 sq. m, depending of the architectural building design and the site conditions (approach possibilities of the crane to the building, jagged building plan).

Complementary elements of the building, facade, partitions, utility works, can be positioned on the assembled structure while the assembly of upper levels is still in progress, shortening the building process and enabling great organisation and flexibility of building construction.

Defining of production and assembly process, with adequate norms, enables building control adapted to local conditions, so that appropriate building dynamic is realised and work dead line is reached in time. The IMS Building Technology transfer comprises local labour training for all those processes, with temporary supervision by the IMS Institute experts.

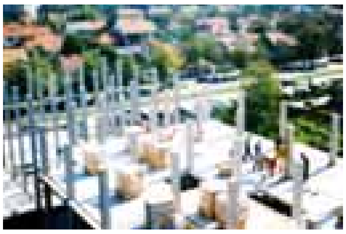


BASIC IMS SYSTEM ELEMENTS

Columns, continual through maximum 3 stories (depends on their cross-sections and storey height or possibilities of the crane used for erection), possessing square cross-section – dimensions: 30 x 30 – 60 x 60 cm.

Floor slabs cover space between columns and can be manufactured with or without concrete ceiling, as one-piece (spans until 3.6 x 4.8 m) or multi-pieces aiming to adapt dimension for transportation and erection (ceilings made for the span 9.0 x 9.0 m are constructed from nine standard elements); the marginal girder and waffle web height is 20-40 cm (depending on column span between which space is covered), floor slab depth between coffer webs is 4-6 cm, and the ceiling one is 3cm.

Cantilever floor slabs, which replace edge beams in architectural solutions where balconies, loggias or other housing space out of column span are required and which are connected only to two columns (as a cantilever) and their height and length correspond to floor slabs near which they are erected, while their maximal width is limited on 1/3 of the longitudinal span. They are waffled and can be with or without concrete ceiling.



Edge girders have a boundary position in order to form frame beams and facade construction. Their lengths and depth are the same as at corresponding floor slabs with which they form a frame beam and their width is chosen according to architectural requirements for the adequate type of facade walls.

Stiffening walls are reinforced concrete panels (minimal depth – 15 cm), which stiffen the frame. They are positioned, by the rule, in the axis of two adjacent columns, having a function to form, together with columns, a structural element from foundations to the roof, ready to receive required intensity horizontal forces (in practice, those elements are often set in concrete in situ, especially at larger spans for the reasons of huge dimension, weight and slow frame erection).

Elevator manholes – in practice those elements are set in concrete in situ, because of non-rational series (small number of elements in constructing building in relation with the mould price for manufacturing within the own section), which, by the rule serve for the acceptance of horizontal forces together with stiffening walls.

Stair elements for one-flight, double-flight or triple-flight stairs, with monolith or prefabricated steps.

The envelope of the building – facades and roofing, as well as interior walls and surfaces, installations and equipment are not standardized. That means that any type of local material or procedure can be applied in order to obtain sustainable, energy-efficient and cost-efficient housing. This facilitates and allows building in respect to the local aesthetic and cultural values.

Results

The application of this technology helped to resolve housing problems in different parts of the world, providing decent homes for the low-income families, with respect to the natural and social environment conditions. It allowed the governments to build hospitals, schools, kindergartens and other public welfare edifices.

IMS Building Technology has successfully been implemented in the production of high, medium and low-standard housing, in various parts of the world, for small individual houses and skyscrapers, for residential estates and commercial or public edifices and industry.

Enclosed on the following page is a table providing information on the approximate cost of an IMS structure. It is an example of the Bill of quantities for the prefabricated structure with the module of 4.20 x 4.20 m. If you fill out the local prices of materials and labour, you will get an estimate of the total cost of building the IMS prefabricated skeleton. Prices are given per 1 m2 of gross building area, and include only the production and assembly of the IMS structure and shear walls. The cost of the foundations is not included in this calculation

Bill of quantities for an IMS structure with the structural module of 4.20 x 4.20 m

Prefabricated primary (frame) structure (no foundations, shear walls included), prices per 1 m^2 of gross building area.

No.	DESCRIPTION	QUANTITY	UNIT	UNIT PRICE [US$]	TOTAL PRICE [US$]
1	**Concrete**				
1.1	Pre-cast elements, M40	0.14	m^3/m^2		
1.2	Cast in-situ, M40	0.01	m^3/m^2		
2	**Steel**				
2.1	Ribbed bars ST 40R	6.25	kg/m^2		
2.2	Smooth bars ST 35S	3.56	kg/m^2		
2.3	Mash	3.02	kg/m^2		
2.4	Strand ø 15.20; 1670 N/mm^2	1.90	kg/m^2		
3	**Anchorages 162 kN**	**0.18**	**pcs/m^2**		
4	**Lifting anchors Rd 24**	**0.71**	**pcs/m^2**		
5	**Cement mortar**	**0.22**	**dm^3/m^2**		
6	**Grout**	**0.22**	**dm^3/m^2**		
7	**Sawn-wood**	**0.0008**	**m^3/m^2**		
8	**Oil for coating of moulds**	**0.121**	**dm^3/m^2**		
9	**Water**	**6.00**	**dm^3/m^2**		
10	**Electric power**	**0.07**	**kWh/m^2**		
11	**Labour**				
11.1	Factory	2.55	h/m^2		
11.2	On site	0.94	h/m^2		
12	**Technical documentation ***		**$US\$/m^2$**		
13	**IMS Fees ***		**$US\$/m^2$**		
14	**Equipment amortization ***		**$US\$/m^2$**		
15	**Transport of elements (50 km)**	**0.38**	**t/m^2**		
16	**Styrofoam (if applied)**	**0.11**	**m^3/m^2**		
	SUBTOTAL:				
17	**Overhead costs ****				
18	**Anticipated profit ****				
	TOTAL PRICE:				

NOTICE:

Total weight of IMS structure:	Ws = 0.38 t/m^2.
Price for anchorages (No.3):	CIF Mediterranean Port
Costs marked with*:	as per project and annual production
Costs marked with**:	as per local conditions

International interest

IMS Building Technology is today used on all continents. A large number of buildings constructed all over the world using this technology, is a clear proof of interest generated by the innovation. The quality of the solution has been proved in practice.

The 50-year-old concept has been constantly upgraded and is today even more superior in comparison to other contemporary building systems.

The IMS system has been certificated by various institutions worldwide: Ministry of Public Works, Italy, Ministry of Construction, Cuba, TbilZNIIEP Institute, Georgia, EMI, Hungary, Central Scientific – Research and design – Experimental Institute for the Construction of Complex Building Structures, Russia, Building Research Institute, Ministry of Construction, China.

Using IMS Building Technology in other countries

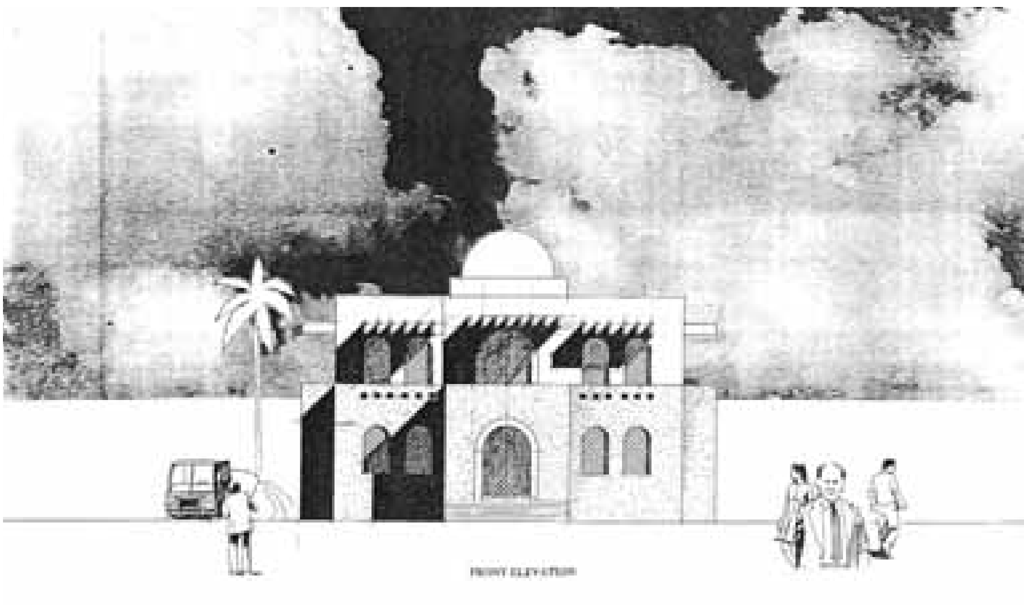
The Building Technology was developed in the Institute for testing of materials (IMS). The IMS Institute is an independent scientific research organization, whose fundamental activity is the scientific research and its implementation in the field of building construction, residential building, prestressing systems, building materials technology, equipment control in thermo and hydro plants, building physics and all other problems related to building industry in general. During its eight decades long and rich history, IMS Institute has participated in the largest building projects in the state as well as abroad, and therefore achieved the reputation of an independent research and consulting organization. Since its beginnings, the IMS Institute has maintained close relations with the Belgrade University and the Serbian Academy of Arts and Sciences, that enabled university students and researchers to test their theories in practice in IMS laboratories, but it also provided academic support for the engineers who designed daring structures and new technologies.

The IMS skeleton has been tested in theory and experimentally at the IMS laboratories as well as in other institutions worldwide. It has successfully resisted to various possible loads (static, dynamic, seismic, impact, fire...), showing high safety coefficients. The IMS system holds the certificates of various institutions worldwide, such as: Ministry of Public Works, Italy, Ministry of Construction, Cuba, TbilZNIIEP Institute, Georgia, EMI, Hungary, Central Scientific – Research and design – Experimental Institute for the Construction of Complex Building Structures, Russia, Building Research Institute, Ministry of Construction, China.

To adopt the IMS Building Technology, the first thing is to contact the experts of the IMS Institute in Belgrade. They will provide all necessary information regarding the possibilities of application for every single case. There are elaborate questionnaires for interested parties, which help IMS engineers propose the optimal solutions.

If an agreement is reached, IMS engineers will then design the production facilities and selected structural elements. Necessary equipment has to be supplied, either by the IMS Institute, or other independent parties. Only the IMS-specific equipment has to be delivered by the IMS Institute.

Optionally, IMS Institute can provide architectural and structural designs for buildings. Since designing in the IMS system is not complicated, local engineers can usually be trained to work without supervision, especially in case of less complicated buildings.



INITIAL INVESTMENTS

The largest part of the investment is the supply of the construction equipment. An average construction company usually has the majority of the equipment for the production and assembly of IMS system elements, as those are standard building tools and machines.

In the process of the transfer of technology, the IMS Institute provides the following services:

- Delivers all required technical documentation necessary for the application of the system. Included in this is the right to use the IMS Building Technology.
- Designs the production facilities and system elements. Supervises the construction and installation of the production plant. Provides technical assistance and training of local staff.
- Designs the first buildings. Provides technical assistance and training of local engineers to design using the IMS system.
- Supervises on-site the construction of the first project. Provides technical assistance and training of local assembly teams until the finish of the construction works on the first building.

All these listed services represent an insignificantly small percentage of the total initial investment required for the application of the IMS Building Technology.

The cost of the initial investment depends on various project-specific conditions, such as: the planned production capacity, the existing construction equipment, infrastructure (power and water supply, roads), availability of production materials, actual prices and other local conditions.

To learn more

IMS Institute web site: **www.institutims.co.yu**

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Contacts

For further information on the IMS Building Technology, please feel free to contact:

IMS Institute Belgrade
Department for Building Technology and Structures
Bulevar vojvode Misica 43
11 000 Beograd
SERBIA & MONTENEGRO
phone: +381 11 2650 322; 2650 483
fax: +381 11 3692 772; 3692 782
e-mail: office@institutims.co.yu

Predrag Napijalo, B.Sc. Architect
e-mail: predrag.napijalo@institutims.co.yu

Goran Petrovic, B.Sc. Architect
e-mail: goran.petrovic@institutims.co.yu
phone: +381 11 2652 094
phone/fax: +381 11 3691 469; 2651 186

The IDEASS Initiative - Innovation for Development and South-South Cooperation - is promoted by the following international cooperation programmes: ILO/Universitas, UNDP/APPI, and by the UNDP/IFAD/UNOPS Human Development and Anti-Poverty Programmes, currently active in Albania, Angola, Colombia, Cuba, El Salvador, Guatemala, Honduras, Mozambique, Nicaragua, the Dominican Republic, Serbia, South Africa and Tunisia. The cooperation initiative grew out of the major world summits in the 1990s and the Millennium General Assembly; it gives priority to cooperation between protagonists in the South, with the support of the industrialised countries.

The aim of IDEASS is to strengthen the effectiveness of local development processes through the increased use of innovations for human development and decent working conditions. By means of south-south cooperation projects, it acts as a catalyst for the spread of social, economic and technological innovations that favour economic and social development at the local level. The innovations promoted may be products, technologies, or social, economic or cultural practices. For more information about the IDEASS Initiative, please consult the website: **www.ideassonline.org.**

IDEASS

Innovation for Development and South-South Cooperation

UNDP's Anti-Poverty Partnership Initiatives (APPI) Programme is a tool designed to assist governments and social actors to establish and apply national policies for reducing both poverty and social exclusion, based on local integrated and participatory development practices.

The human development and anti-poverty programmes run by UNDP, IFAD, ILO and UNOPS promote integrated and participatory local development processes within the framework of national policies, with the support of public, private and civil society actors. These programmes provide the framework within which donor countries and communities in the industrialised countries can collaborate in an organised way, through descentralised cooperation. It is in this framework that south-south cooperation projects will be carried out via the Initiative.

The ILO/Universitas programme (decent work through training and innovation) encourages the use of innovative solutions to problems in human development, especially in the world of work. To achieve this, it carries out action-research activities and trains decision-makers and personnel working in local development.