

Potential of Progressive Construction Systems in Slovakia

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Abstract. Construction industry is a sector with rapid development. Progressive technologies of construction and new construction materials also called modern methods of construction (MMC) are developed constantly. MMC represent the adoption of construction industrialisation and the use of prefabrication of components in building construction. One of these modern methods is also system Varianthaus, which is based on, insulated concrete forms principle and provides complete production plant for wall, ceiling and roof elements for a high thermal insulation house construction. Another progressive construction system is EcoB, which represents an insulated precast concrete panel based on combination of two layers, insulation and concrete, produced in a factory as a whole. Both modern methods of construction are not yet known and wide-spread in the Slovak construction market. The aim of this paper is focused on demonstration of MMC using potential in Slovakia. MMC potential is proved based on comparison of the selected parameters of construction process – construction costs and construction time. The subject of this study is family house modelled in three material variants – masonry construction (as a representative of traditional methods of construction), Varianthaus and EcoB (as the representatives of modern methods of construction). The results of this study provide the useful information in decision-making process for potential investors of construction.

1. Introduction

The construction industry in Slovakia has been relying heavily on traditional construction technology. Buildings are usually constructed by the conventional cast in-situ methods. Recently, the modern methods of construction (MMC) are apply more for its performance improvement in construction, improvement of economic, environmental and social aspects of construction.

MMC represent the adoption of construction industrialization and the use of prefabrication of components in building construction. It is defined as a construction technique in which components are manufactured in a controlled environment (on or off site), transported, positioned and assembled into a structure with minimal additional site work [1]. Modern methods of construction in construction industry includes the industrialized process which the components are conceived, planned, fabricated, transported and erected on site.

MMC balance the combination of the software and hardware factors. The software factors (figure 1) include system design which study the requirements of end user, market analysis, development of standardized components, establishment of manufacturing and assembly layout and process, allocation



of resources and materials and definition of a building designer framework. The software factors provide a prerequisite to the creation of the conducive environment for MMC to expand.

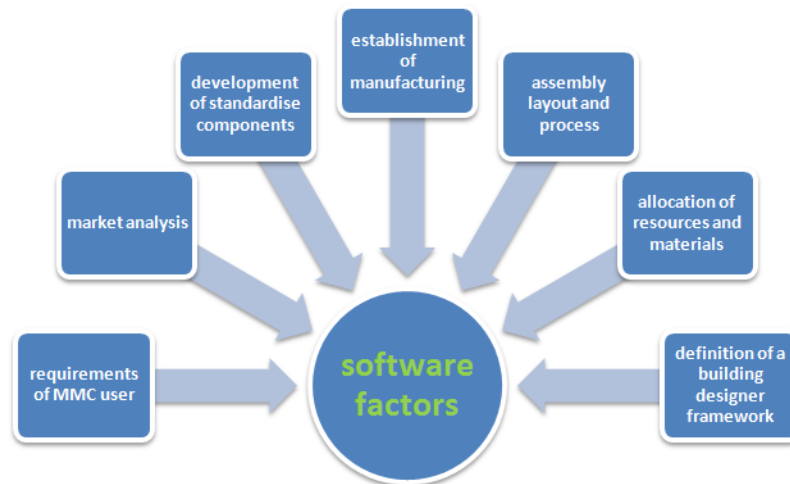


Figure 1. Software factors of modern methods of construction

The hardware factors (figure 2) are categorized into four major groups, which are included: (i) blockwork system, (ii) frame and beam system, (iii) panel system and (iv) volumetric system. MMC systems vary considerably, the nuances of which include modular, framed, panelised and volumetric variants which involves modular, framed, panelised and volumetric approaches. For instance, framed systems present load-bearing construction and is closed by panels. Panelised systems are produced in a factory and assembled on-site to produce a three-dimensional structure. Conversely, volumetric construction involves the production of three-dimensional modular units in factory conditions prior to transport to site. The blockwork system consisting of lump sophisticated elements of different materials. The construction method of using conventional bricks has been revolutionized by the development and usage of interlocking concrete masonry units (CMU), lightweight concrete blocks and insulated concrete formwork (ICF).

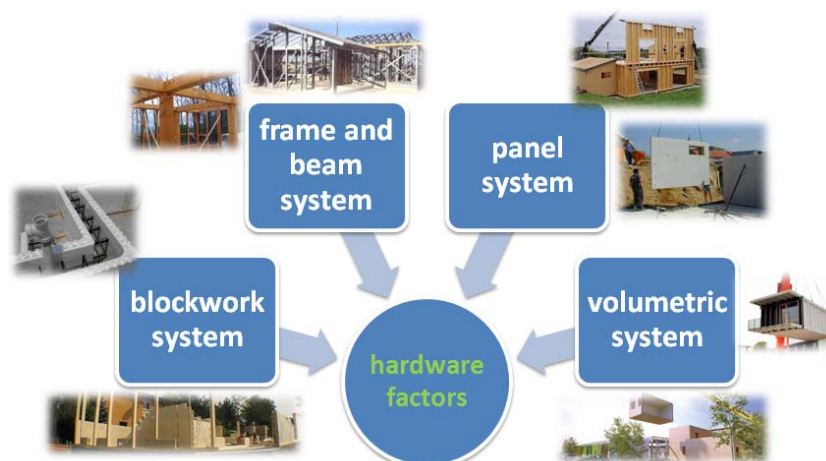


Figure 2 Hardware factors of modern methods of construction

Each construction system can be evaluated and there are distinguished several drivers and barriers for implementation of MMC to the current construction industry [2, 3]. Currently, environmental aspects of the investment have received clients' increasing attention [4]. Adopting of MMC has the

following main drivers to the practitioner when compared to the conventional construction method [5,6,7,8,9,10,11,12]. However, despite these undisputed benefits some stakeholders think, that MMC has not yet had the impact they expected, or hoped for and they are little bit sceptical about using MMC [7]. Same authors who described drivers of using MMC, pointed also to barriers that prevent the spread of MMC in many countries.

2. Research material and methodology

The aim of this paper is to demonstrate the using potential of MMC in Slovakia. MMC potential is proved through comparison of the main economics parameters of construction process - construction costs and construction time. Comparison was carried out by research of case study focused on three material variants of family house.

2.1. Research material

The object of case study is a two-storey family house with gross floor area of 89 m² and floor area 147 m² (figure 3).

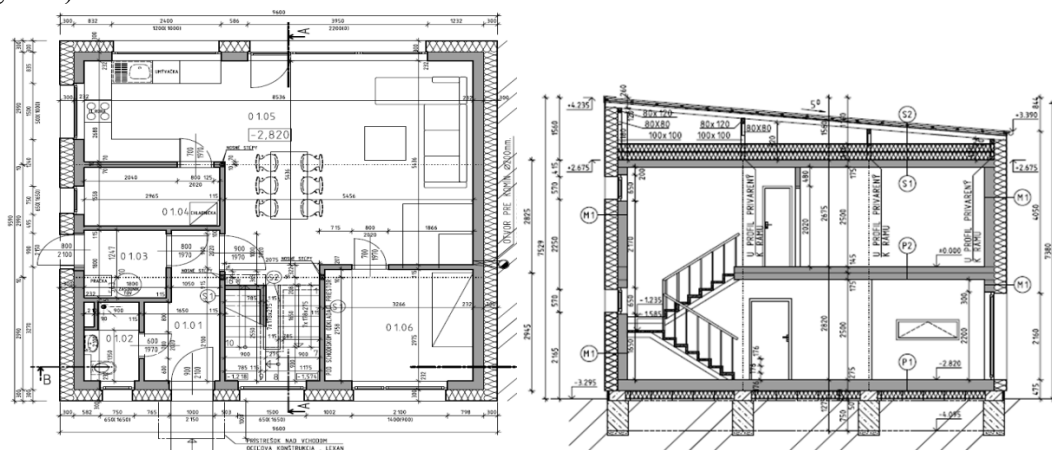


Figure 3. Ground plan and section of solved family house

The selected economic parameter was compared for three material variants of this construction having regard to the shape and the dimensions of the original building. Material variants were carefully selected to prove the MMC using potential in Slovakia. Variant “A” is a representative of the most widely traditional method of construction – masonry construction by YTONG bricks. The other two variants, “B” and “C”, presented the modern methods of construction which are not widely used in Slovak construction market.



Figure 4. Insulated concrete formwork of Varianthaus system: a) load-bearing reinforced external wall, b) Varianthaus system framework, c) house built by system Varianthaus, [13]

Variant “B” presents a construction system VariantHaus which belongs into group insulated concrete formwork (ICF) (figure 4) based on the Neopor material. This new developed material Neopor provides an insulating material that offers significantly better thermal insulation than other products currently available. Variant “C” is a representative of MMC panel system, particularly insulated precast concrete panels EcoB (figure 5) which consists of two mutually joined materials - a bearing wall of precast concrete and insulation based on Neopor material.



Figure 5. Insulated precast concrete panels EcoB: a) corner elements of EcoB, b) load-bearing panel of external wall, c) EcoB system framework, [14].

Family house in all three variants was divided into two main parts: (i) frameworks and (ii) finishing works, which were assessed from economic aspect. The material characteristic of frameworks is different (according to particular construction system) and the finishing works are the same.

2.2. Research methodology

The aim of this paper is to demonstrate the using potential of MMC in Slovakia based on the comparison of main economic and technological parameters of construction process and comparison of drivers and barriers of selected construction systems.

The comparison of construction time (CT), as main technological parameter, for all three material variants was made through construction schedule processing in programme MS Projects. The input for CT calculation was the CT calculation of individual i -th construction process CT_i , which was set according the formula:

$$CT_i = \frac{V_i * LI_i}{w_i * t_s} \quad [\text{day}] \quad (1)$$

where: V_i = volume of i -th schedule items [unit of measure for volume - t, m, m^2 , m^3]
 LI_i = unit labor intensity of i -th schedule items [NH.UM $^{-1}$]
 w_i = number of workers for i -th schedule items
 t_s = time of shifts [h]

The construction costs (CC), as main economic parameter, were set for purpose of comparison through the detailed quantity take off processing and assigns the unit costs for all items in software Cenkros Plus (the most widely used software for a cost estimation and management of building production in Slovak construction market). CC for construction were calculated according to the formula:

$$CC = \sum_{i=1}^m V_i * c_i \quad [\text{EUR}] \quad (2)$$

where: V_i = volume of i -th budget items [m^3]
 c_i = unit price of i -th budget items [EUR. m^{-3}]

Identification and analysis of the main drivers and barriers of selected construction systems implementation in Slovakia were achieved through structured interviews with representatives of companies dealing with the construction of houses by Varianthaus system, EcoB system and by

YTONG bricks. The structured interview was divided into two basic parts (drivers and barriers of system implementation in Slovak construction market) and partial parts (construction time, industry skills shortages, better quality product, health and safety benefits, environmental benefits, public attitude, unproved durability of prefabricates, uncertainty about demand, attitude of house construction industry and prefabricated construction skills).

3. Results and discussions

The conventional construction methods have been known and proven to be wasteful, dangerous and messy due to the process of constructing buildings. On the other hand, the application of modern methods of construction (system Varianthaus and EcoB) has distinct advantages. The structured interview results confirmed some of them (table 1).

Table 1. Confirmation of drivers and barriers for use of selected construction systems in Slovakia.
Source: authors

		YTONG bricks	Variant- haus	EcoB
DRIVERS	Faster construction time	✗	✓	✓
	Fewer people on-site	✗	✗	✓
	Better quality product	✓	✓	✓
	Health and safety benefits	✗	✗	✓
	Increases profits	✓	✗	✗
	Easy to comply with building regulations	✓	✓	✓
	Environmental benefits	✗	✓	✓
BARRIERS	More expensive than traditional construction method	✗	✓	✓
	High investment costs	✓	✓	✗
	Public attitude	✗	✓	✓
	Unproved durability of system's components	✗	✓	✓
	Uncertainty about demand	✗	✓	✓
	Attitude of house building industry	✗	✓	✓
	Lack of workers construction skills	✗	✓	✓

Note: ✓ confirmed claim; ✗ rejected claim

Slovak construction market not very trustingly accepts Varianthaus system and do not accept system EcoB, yet. Currently there are witnessing the indifference about these MMC systems. The moderate using of MMC systems confirms barrier - uncertainty about demand (on both sides – investors, as well as constructors). Only two-construction companies deal with system Varianthaus and only five houses are built in Slovakia by this system. These companies are willing to contribute to the expansion of modern methods of house construction with high energy standards. This is also the reason why the reference house from system EcoB was built. There is only one house built by this system in Slovakia, yet. This fact also confirms even another barrier – attitude of house building industry to acceptance a new, modern, progressive construction system. The level of application of each technology market is closely related to construction costs.

The comparison of construction costs (table 2) for Varianthaus system, system EcoB and masonry construction pointed to the fact that application of MMC system is more expensive than construction from YTONG bricks. House built from Varianthaus construction system particularly in 20% and house from EcoB system particularly in 10%. On the other hand, the application of Varianthaus system has “hidden” advantages - lower thickness of external walls by about 150 mm (i.e. more floor space), more stable monolith bearing structures in the event of uneven subsidence, landslides or earthquakes. These benefits can compensate the higher investment costs for the potential investors.

The construction time of frameworks and (ii) finishing works for all three variants is in Table 2. Construction time (table 2) using the Varianthaus system can be reduced by 20% within comparison to YTONG construction. So, this can save valuable time. Moreover, it helps to reduce the monetary losses. Because of EcoB's higher degree of prefabrication we can reduce on-site construction time in 80% within comparison to masonry construction. The shorter construction time can increase profits of constructors. Due to the increased profits, it is necessary to increase the level of application of MMC system on the market. In conditions of Slovak construction market the drivers "increased profits" was not confirmed. Surprisingly, the number of the workers using the Varianthaus system is the same as in the construction by YTONG bricks. This benefit has not been confirmed. On the other hand, this benefit has been confirmed when system EcoB is used.

Table 2. Comparison of construction time and construction costs of selected construction systems.
Source: authors

	CT - frameworks [days]	CT - finishing works [days]	CC – frameworks [EUR]	CC - finishing works [EUR]
YTONG bricks	115	29	52 600	67 000
Varianthaus	95	25	80 900	68 600
EcoB	12	23	64 350	69 250

Note: CT – construction time; CC – construction costs

The Varianthaus system elements are produced in the factory. The quality of these elements is more secured because the manufacturer imposed strict quality control over the materials, production process, the curing temperature, etc. The concrete mix (for concreting of IFC) and the stripping time can be controlled and monitored closely and thus produces high quality components with high aesthetic value. Unfortunately, structural elements can be damaged during the transport or manipulation.

EcoB's panels are also produced in the factory, so their quality is strictly controlled. On the other hand, the corners of system and joints between the panels are very specific (Figure 6). It is done on-site and the poor-quality connections may result in deterioration of the whole building especially in terms of thermal parameters.

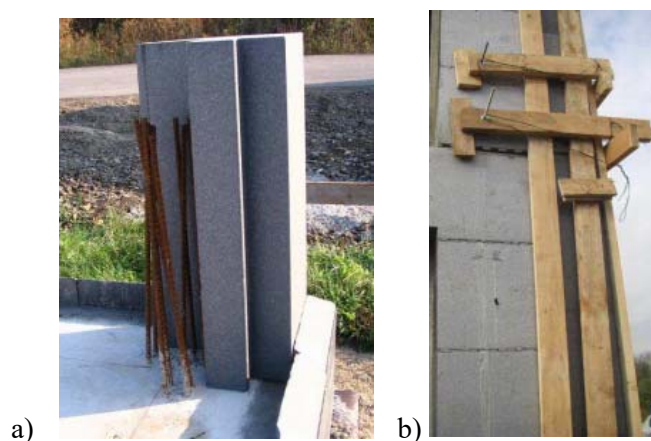


Figure 6. Corners within EcoB construction system a) insulated element of corner b) concrete of corners, [14]

Varioushouse elements provide a safety working platform for the workers to work on and therefore the risk of minor accidents and fatal accidents can be prevented. According to the answer of

respondent, amount of work on site is comparable to masonry construction; therefore, the risk of injury is the same as for construction from YTONG bricks. Also, environmental parameters (transport – 1 drive, volume of construction and demolition waste – 0,2 t) are the same as for masonry construction. The health and safety benefits and environmental benefits have not been confirmed because of they are identical to masonry construction. EcoB system consists of panels that require lifting device. Therefore, it is necessary to observe safety measures for the installation works. However, on-site works last much shorter than within the masonry construction and there are fewer workers on construction site. It has a positive effect on health and safety benefits of this construction system. Also, environmental benefits are undeniable. Because of Ecob's higher degree of prefabrication than YTONG system, there is less construction and demolition waste on site (0,05t).

The driver, in compliance with building regulations, has two levels. First level is the obtaining of construction permissions. Second level is the declaration of conformity. Each construction material or products has to have the declaration of conformity which is related to the fulfilment of the quality requirements of building materials and products according to the Slovak standards. Varianthaus system and EcoB system is holder of declaration of conformity. Also, investor obtained the construction permissions. So, comply with building regulation is comparable with masonry system thus the drivers "easily comply with building regulations" is confirmed.

Based on the structured interview, the most significant barrier for application of Varianthaus system and system EcoB in Slovakia is lack of prefabricated construction skills and public attitude. The Slovak construction companies are still learning and continually increasing their skills focused on these systems. This is evidenced by two construction examples of house (figure 7). The unpredicted defects of insulated concrete formwork elements during construction works was a cause of damage window and inner corner.

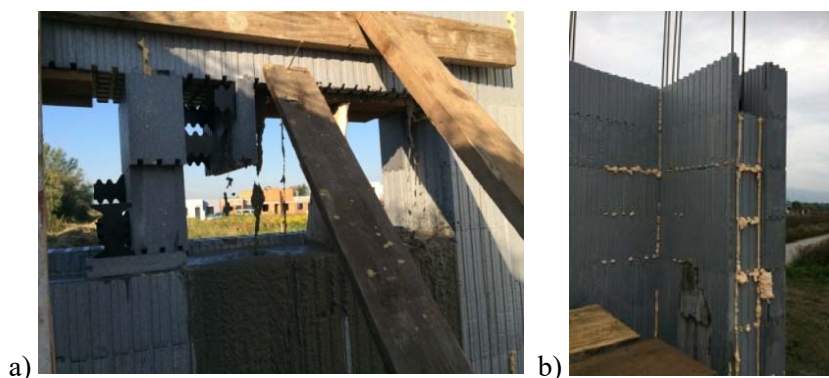


Figure 7. Construction of house by Varianthaus system: a) unpredicted damage of window formwork, b) unpredicted damage of inner corner formwork.

4. Conclusions

Modern methods of constructions should not to be perceived as a threat to conventional methods. The modern methods of construction present the latest trends of construction sector to sustainability through prefab construction, permanent modular construction, energy efficiency, single-design model and materials, as well as insulated concrete formworks. Currently, the MMC are increasingly becoming more popular because of their undisputed benefits in technological, economic, environmental and social areas and gradually find their place in the market in Slovakia, where they are primarily used in residential buildings. The submitted paper identified and analysed the main drivers and barriers of Varianthaus system and EcoB system implementation in Slovakia. It was confirmed the significant drivers to implementation of Varianthaus system in Slovakia (faster construction time, better quality product, easy to comply with building regulations, environmental benefits) and the

significant barriers (more expensive than traditional construction method, high investment costs, public attitude, unproved durability of prefabricates, uncertainty about demand, attitude of house building industry, lack of prefabricated construction skills). Despite of the benefits, MMC has not been effectively implemented in Slovak republic. According to this study, we can claim that the main barriers hindering the increased use of these methods are preference of traditional methods of construction and lack of expertise in implementation and installation.

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