Development Directions for Various Types of the Light Wood-Framed Structures

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Abstract. The paper presents current trends in the development of the wood-framed structures. Authors describe the evolution of the technology of implementation, the production process of precast elements of buildings as well as selected realization on the site of these kinds of structures. The attention has been paid to the effect of implementation phases on construction and erecting technology of the wood-framed structures. The paper draws attention to the importance and enhancement of structural analysis of structures in individual phases of building realization.

1. Introduction

The wood-framed technology of building construction is used in many countries around the world. The participation of this type of construction in the entire building market varies depending to the country [1]. These types of buildings are very popular in the Scandinavian countries, England, North America or Japan.

Increasing popularity of the wood-framed structures is a result of many advantages as: low workload, lack of wet processes, short realization time, lightweight, good ecological parameters, use of renewable raw materials.

The untreated solid wood as well as the converted wood is used. The converted technologically modified wood could be made of glued veneers, boards (e.g. LVL, OSB, plywood, chipboard, etc.) or chemically modified (e.g. Accoya®). Recently it could be observed that erected construction are often made in technology of the wood-framed structures and this applies not only to single-family residential houses and one- or two-storey family building but also to multi-storey residential and multifamily buildings. There are also attempts to build in wood-frame technology tall buildings, mainly based on glued or modified wood.

Another tendency is to prepare building components such as walls, floors, roofs in the form of precast in factories. This affects the speeding up of the realization process of construction, but also it is improving the quality of the factory made precast walls, floors or roofs. The lightweight of this type of the structure allows the transport of structural components even at great distances. However it creates the next phase of production, starting from manufacturing in the factory, through the transport, ending with assembly. This fact imposes the importance of design of this type of structure for individual phases [2].

The paper will present current trends in the development of technology and methods of wood-frame buildings.
2. Implementation technology
The technology of implementation evaluates from the execution of all works on the site, by partial prefabrication, through the prefabrication of individual building elements such as walls, floors, roofs, up to the modular spatial parts of buildings [3].

Erecting work on the construction site with numerous construction elements and then mounting the insulation and facade layers is shown in figure 1.

![Figure 1](image1.png)

**Figure 1.** Erecting work on the site: a) construction of beam and stud elements, b) filling the wooden frame by isolation layer of hollow block, sawdust concrete or concrete with sugar cane fibers.

Partial prefabrication consists of the manufacturing of small-dimensions items such as blocks or hollow blocks, which together with the wooden framing make up the construction of buildings. The construction of wall structures based on hollow blocks is presented in figure 2.

![Figure 2](image2.png)

**Figure 2.** Construction of the wall made of the hollow blocks: a) hollow blocks in the wall layer [4], b) visualization of construction corner [5].

The next step in the development of light wood-frame buildings is the production of large-dimensions panel walls, floors and roofs made of wooden framing and sheathed by the OSB, chipboard or plywood panels, and finally the assemblage of these panels into spatial modules as part of the building, as shown in figure 3.

Modular elements are often pre-finished by window and door frames and facade elevation layers.
3. Factory production of building elements

The production of precast elements of building in manufacturing factories and subsequently the elements transport to the erection site, assemblage and exploitation cause the successive phases of building realization. The phases are shown in figure 4.

The elements made in precast factories and transported to the erecting site are assembled into entire building, as shown in figure 5.

The accuracy of assembly and proper realization of joints is achieved as an important technological process and controlling in this case [6].
4. Design of structural elements and buildings

Prefabrication of panel and modular components and phases of building implementation imply incorporating in the computational analyzes those steps in which the static schemes and the loads are changing. In opposition to previously used 2D calculation models [7, 8] the 3D methods are used to develop the analyzed problem [9, 10] as shown in figure 6.

![Figure 6. Calculation models for light wood-frame structures: a) 2-dimensional [7], b) 3-dimensional [9].](image)

Analytical methods like Force Method or Direct Displacement Method allow calculation only in very simplified cases. Development of computer science and faster computer machines caused the calculation of more complex numerical problem stop to be a problematic. Issues with great number of unknowns could be develop using Finite Element Method.

Aggregation of global stiffness matrix is being done by introducing global coordination system, boundary conditions and summation of particular elements of its various types.

\[
K = \sum_c \sum_t \sum_e K_e
\]

(1)

Similar situation is for load vector, which is presented as follows:

\[
P = \sum_c \sum_t \sum_e (P_h + P_v)
\]

(2)

where:

- \(K_e\) – element stiffness matrix,
- \(c\) – individual components of the building (walls, floors, etc),
- \(t\) – types of elements (studs, beams, connectors, sheathing),
- \(e\) – particular elements of given type,
- \(P_h, P_v\) – respectively horizontal and vertical loads.

Displacement vector for beam finite elements is given as:

\[
q_b = \{u_1, v_1, w_1, \phi_{x1}, \phi_{y1}, \phi_{z1}, u_2, v_2, w_2, \phi_{x2}, \phi_{y2}, \phi_{z2}\}
\]

(3)

while for 4-node shell elements is presented as:

\[
q_s = \{u_1, v_1, w_1, \phi_{x1}, \phi_{y1}, \phi_{z1}, ..., u_4, v_4, w_4, \phi_{x4}, \phi_{y4}, \phi_{z4}\}
\]

(4)

The stiffness matrix is derived from standard finite element method relationships. The final set of equations of the calculation model, which may be nonlinear, has the form:

\[
K(q)q = P
\]

(5)

5. Summary

As mentioned above, the technologies of buildings made of wooden frames evolve from execution directly on the construction site to the full factory production. Recently, the level of technological advancement is the production of ready-made spatial modules covering a part of the completed buildings. Factory production is conducive to the preparation of pre-finished elements with higher quality. However, it introduces to the technological process the implementation phases: production of
components, transport of the modules, assembly the modules into an entire building in the erecting site. An important element of this technology is the accuracy of assembly and properly made connections. In addition, prefabrication and phasing of investment process create new, higher demands on structural, technological and organizational design.

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