EXPERIMENTAL TESTS AND ANALYTICAL MODELS OF LIGHT WOOD-FRAMED BUILDINGS

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Summary:
Timber is excellent ecological material. It is biodegradable and not polluting the enviroment after destruction, but also it is very heterogeneous and has got various material properties. In opposition to concrete and steel structures the behavior of timber framed constructions is not properly recognized.
The authors presented in this paper a comprehensive overview of the problem of light wood-framed buildings. The wide range of experimental studies and the computational models of individual elements as well whole building in timber frame technology provided and developed in the world of science was presented.
The authors also presented the experimental tests provided at Bialystok University of Technology. The range of studies, tested specimen and the results and conclusions was included in this paper. The developed numerical model using finite elements to describe behavior of wall and floor elements of wood-frame building was presented. The model had differences to previous models due to proposing the fasteners as beam elements as well the framing and sheathing as shell elements. The only nonlinear elements in proposed model were sheathing-to-framing connectors. The model was compared with the results from experimental studies and gave similar values.
The conclusions was ended this develop paper.

Keywords: light wood-framed building, experimental tests, analitycal models, behaviour of timber walls and floors

Introduction

Buildings erected in lightweight timber frame technology account an insignificant segment of the construction market in Poland in opposition to the monolithic or precast concrete, structural masonry or steel structures. In contrast to other countries such as the United States, Canada, Japan and in Europe Germany or particularly the Nordic countries, this type of construction is very popular and still growing.

The popularity of this type of structure in the world comes from the environmental impact of material the buildings are made, of wood. In the United States, Canada or Finland huge tracts of coniferous forests provide excellent material not polluting environment and biodegradable. A significant feature of the timber is highly resistant to seismic impacts. In case of the Japanese islands exposed to a significant amount of shock, it is very important feature.

Of course the wood is not perfect material. Against positive features timber has negative. This material is susceptible for weather, biological conditions and depends on passing the time. Timber during use is drying unless the moisture protection. The drying

causes the change of transverse dimensions, appearance of gaps in the nodes resulting the higher flexibility and decrease the overall stiffness of the building.

Unlike steel almost homogeneous material or concrete characterized by a small variation of material characteristics, timber is very heterogeneous material. It is characterized by different compressive and tensile strength also dependent on the orientation of the fibers in the structural member.

Each tree grows in its own individual and unique way. In various trees the jars have different dimensions, the side branches appear in different places. This diversity makes the wood is obtained with similar parameters for each lot, but often differ quite significantly between different arts.

The wood frame structures are characterized by a multiplicity of connections, which distinguishes its from other types of constructions. It possible to distinguish connections between wall elements, wall and floor elements or wall and roof elements. Additionally in each structural elements exists connections between elements of timber frame as well the framing and sheathing.

The way the joints are made depends on what is connected. Components of the walls, floors or roofs are combined into one unit with shank fasteners, as nails, bolts, screw or staples. Increasingly the glued joints are used because of higher stiffness than nailed connection. In case of wall to wall, wall to floor or wall to roof connections appears the nodes connected by the bolts or screws but often the rigidity is increased by using woodworking joints.

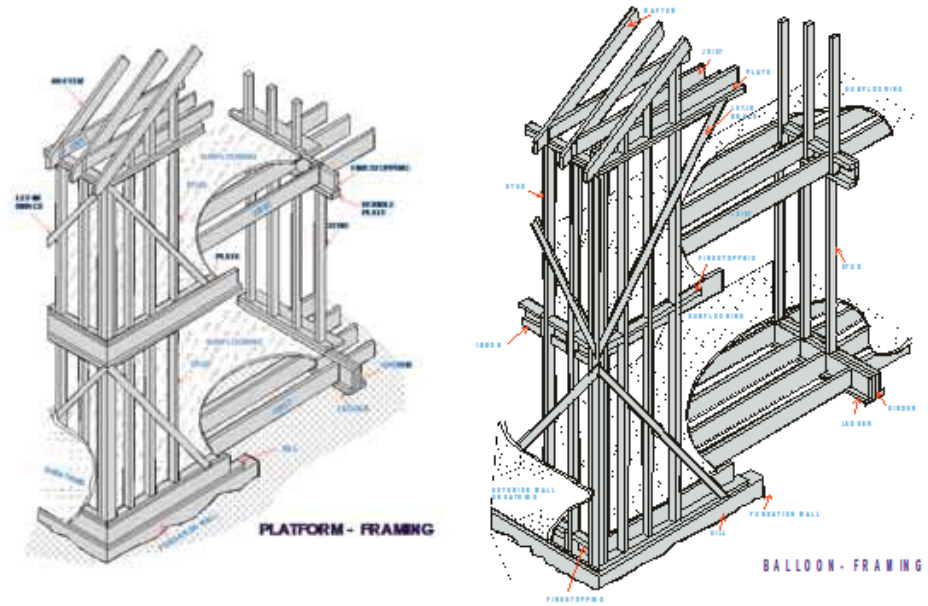


Fig. 1. System of wood-framed buildings: a) platform, b) balloon

The connection of elements in the structure is determined by the type of building that is erected. In platform framing system (Fig. 1a), the ceiling of the lower level is used as a working platform, in the construction of the walls of the next floor. In case of balloon framing system (Fig. 1b) the studs of the walls are raised to the height of the building and floor elements are created by connection of joists with the studs and sheathed by the panels of ceiling.

In balloon framing system it is possible to create joints which greater stiffness. It depends upon the construction of the joint as well as the numbers and type of fasteners used. Disadvantage of this system is reduce the height of the building to the length of timber arts used to create studs.

The opportunity to create high buildings limited only by capacity and stiffness of structural elements is possible using platform framing system. Additionally this system is perfect to use prefabrication, which reduce the time necessary to erect the building according to better implementation of capacity and stiffness of the structural elements.

Although the timber framed construction has more than 60 years, still the issue is accurate analysis of its behavior. The experimental tests and numerical analysis allowed to specify the behavior of construction work but still wide range of its characteristics remain unexplored.

A very important issue is the need to present the work of joints, as well its stiffness, which determines the stiffness of overall structure. The rigidity and thus the flexibility of joints determines the distribution of internal forces between the individual elements, affecting on structure behavior and its capacity.

The great importance for the joint stiffness is the passage of time and the associated drying of wood or the emergence of gaps. The gaps degrades connection accuracy, reduce its stiffness and affect onto overall stiffness of the building, which may result in excessive deformation or buckling.

Experimental tests

Wall elements

Starting from 40’s of 20th century the experimental test of wood-frame structural elements were conducted. Initially the stiffness of walls was provided by corner anchoring or diagonally nailed timber plates. First recommendation for using sheathing panels appeared in guidelines publish in 1949.

Beginning from 50’s the experimental studies focused on test of full-scale building. Soon the researchers found out the easier way to know behavior of wood-frame building is recognizing the behavior of individual elements as walls, floors or roofs.

The experimental tests allowed to observe many aspects of wood-frame structure work. The minimum thickness of sheathing was recognized as 9,5mm. The thickness greater then the limit allows to omit the buckling of panels (Dolan 1989). The limited length of shear wall which provides the cooperation in lateral load distribution is 1,22m (White 1995). The shear-walls of less length should be omitted in stiffness analysis of whole structure.

Influence of openings on element bearing capacity was studied. The empirical equations was developed to calculate the capacity of perforated elements (Sugiyama, Matsumoto, 1994). Property of proposed equations was experimentally verified (Johnson 1997).

Existence of openings affects on shear-wall bearing capacity so to prevent the element of failure it is necessary to use anchor bolts. Using anchoring along each opening increases the capacity and stiffness of shear-wall as well changes the destruction scheme. In the absence of anchoring destruction is uplifting studs and sheathing from bottom framing beam. Due to application the anchor bolts the destruction in provided as cutting the sheathing by the nails (Heine 1997).

The distance between egde of sheathing and lines of nailing affects on the capacity and stiffness. Lower distance causes the 20% less capacity and stiffness. The increase of capacity and stiffness is possible by applying more fasteners connecting sheathing with bottom framing beam (Salenikovich 2000).

The seismic response of wood-frame building is very important when the numbers of earthquakes is increasing. American guidelines ASCE Standard 41 (2007) use very conservative drift level to represent near collapse deformation at 3% limit drift. Experimental studies presented that using lateral braces increase the limit of inter-story drift to 7~10% level (Pei et. al., 2013).

The development of wood frame construction in Poland, as well as the emergence of companies manufacturing these buildings caused the desire to know the behavior of the structures. It resulted in a number of studies carried out at the Bialystok University of Technology (BUT). The aim was to describe the behavior of shear-walls and floor elements and create the calculation model for extensive analysis (Malesza 1997), (Baszeń 2004).

The first tests focused on the three panel shear wall (Malesza 1997). In opposition to more previous studies the structures was loaded by lateral as well vertical load simulating dead load and live loads of upper floors.

Three specimen 3,75m long and 2,75m high was loaded. The framing was made of pine wood class C-27. The studs and horizontal beams had 135x45mm transverse dimension. The stud spacing was 625mm. The framing was one-side sheathed by chipboard 12mm thick. The sheathing was divided to three separate panels 1,25m long and 2,75m high.

Framing connections were provided by two G 5/150 nails on each node. Sheathing-to-framing fasteners were G 2,7/65 nail with 150mm spacing on perimeter and 300mm spacing on the middle stud of each sheathing panels.

The experiment was conducted in three phases. The first phase was the beginning load at 10% destruction load level. In this phase the lateral and vertical loads were applied separately. The second phase was similar to first phase only the level of load was increased to 40%. In last phase the structure was loaded at the same time by lateral and horizontal loads until the destruction appears.

During the tests was observed that nonlinear behavior of sheathing-to-framing connectors affects the nonlinear behavior of the specimen. Shear wall work as plate-plane stress system. It is important due to load eccentricity. The influences on the plate state of work is conducted by sheathing thickness and fastener length.

The next experimental tests focused on aspect of opening in shear wall and it impact on capacity and stiffness of wall element. The second part of the study was the behavior of short length shear-wall (Baszeń 2004).

Four specimen with one sheathing panel 1,25m long by 2,75m high and three specimen 3,75m long by 2,75m high with three separate panels of sheathing was tested. The longer elements had in middle part the window opening (Fig.2).

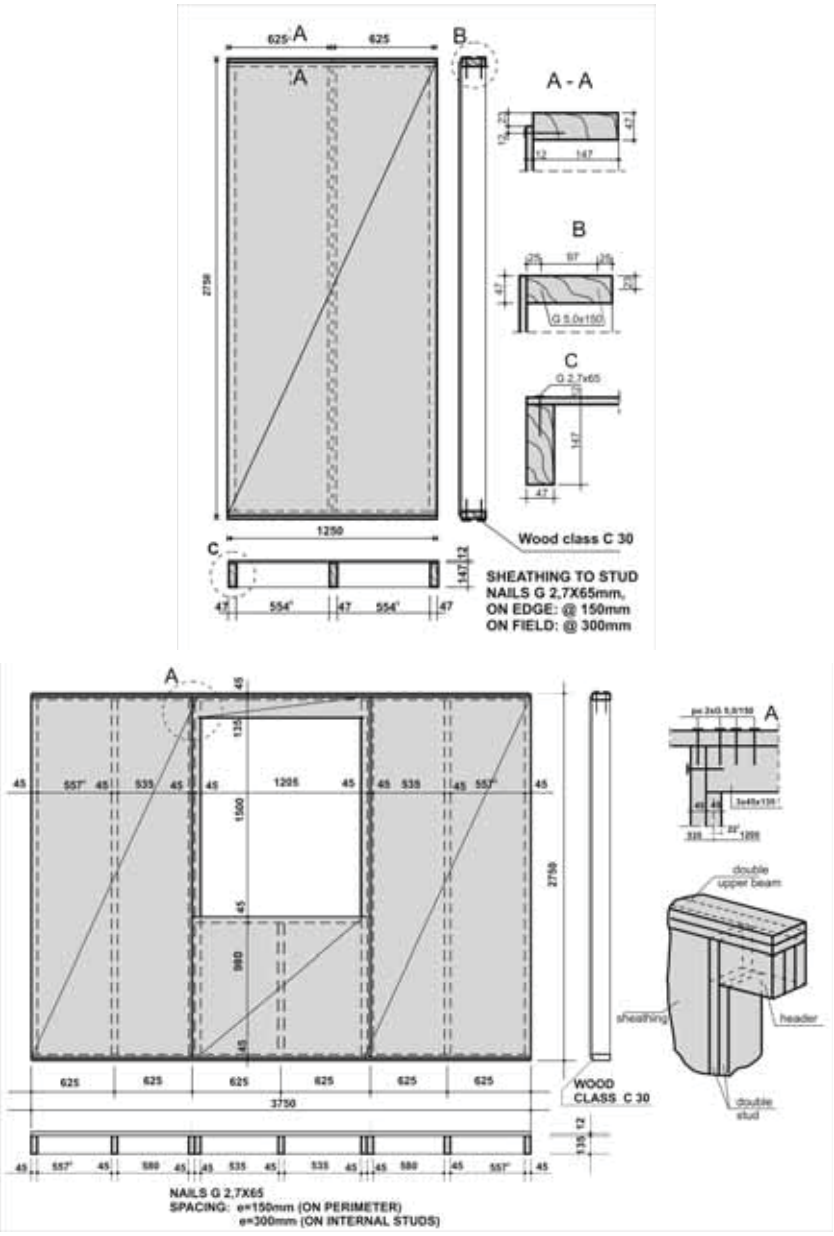


Fig. 2. Wall specimen: a) single wall, b) wall with opening

Framing was made of spruce wood class C-30. The dimensions of framing in single panel wall were 47x147mm, while in walls with opening were 45x135mm. As the sheathing was used chipboard 12mm thick divided to three separate panels with the same length.

Connection in framing was provided by two nail G 5/150 at each node. Sheathing-to-framing connection was made of G 2,7/65 nails with spacing 150mm on the perimeter and 300mm at middle stud.

In single wall the stud spacing was 602,5mm while in wall with opening 625mm. Additionally along the opening were built in two studs. The stud below the opening had length determined by the opening dimension. Additional horizontal beam was built in under opening. Over the opening was introduced the lintel made of three beams with the same dimensions as rest of framing. The lintel was based on the additional studs and connected with modular studs by the nails. The same system, configuration and phases of loads was used as at the previous studies.

During the studies was observed that wall with opening similar to full three panel wall from Malesza's test had accurate stiffness to prevent the destruction deflection. Single panel wall have had inaccurate stiffness to be included in lateral load distribution. That verified conclusions from previous studies (White 1995).

Force distribution between individual elements of wall with opening was at the same level, independent to type of loads. In single panel wall increase of loads, especially lateral, affect the decrease of sheathing in carrying the external load from 40% to 20% level. The decreasing was due to loss of capacity of fasteners.

The stress values in sheathing were greater in cross-section passing through the opening in opposition to cross-section under the opening. Stress in studs in wall with opening was less than in accurate wall without the opening. It depended on more studs in wall with opening.

Destruction of single panel wall followed by uplifting the stud at the same side as application of lateral load. Another scheme of destruction was the lost of sheathing-to-framing fasteners capacity at top corner opposite to lateral load.

Destruction of walls with opening followed by the lost of sheathing-to-framing fasteners capacity on the stud opposite to lateral load. Due to the existence of independent panels had also been the pressuring and the crushing of the panels.

Floor elements

Floor elements behave more like rigid body rather than elastic (Yokel et al., 1973), (Phillip et al., 1993). That is the reason why its have less deformation then wall elements. It results the designing is often limited to use of tabular summaries contained in design guidelines, for example, ATC (1981). The downside of using guidelines is taking into account only typical shape of building but exclude existence of openings. The problem also appears when the shape of building is different to rectangular.

Experimental study of floor elements started in the 50's of last century. One of the first test was carried out by Countryman (1952), later floors was investigated by Tissel (1967).

The first attempts to estimate openings impact on floor behavior was made in 1981. The tests were not conducted according to APA preferences, so the results were not properly verified (Tissel, Elliot, 1981).

Also in Japan wide studies over floor elements were conducted. Unfortunately most of the results were printed only in Japanese. The one of Japanese researchers, Kamiya, conducted wide experimental studies resulted proposed „membrane-to-brace" calculation model. The model gave results similar to experimental data as results calculated according to ATC guidelines (Kamiya 1990).

Next experiments allowed to develop the model to include existence and position of openings (Kamiya 1992). The aim of next step of floor element studies was concentration of shear force around openings and generation of axial forces in framing (Kamiya, Itani, 1998).

In BUT together with experimental studies of walls the test of floor elements were conducted. The same experimental stand were used as during wall tests, so floor elements was loaded in vertical position. The position of specimen allowed application only in-plane loads simulating lateral forces.

The were tested four specimen in two series by two elements. The dimensions of specimen was 2,75x3,75m for first series and 2,75x3,6m for the second (Fig.3).

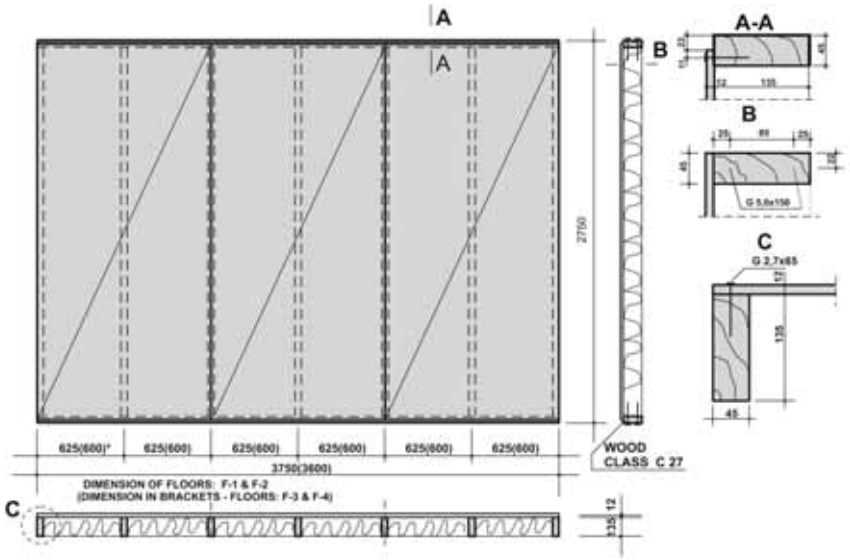


Fig. 3. Floor element

Framing was made of wood class C-27 with transverse dimension 45x135mm. Joist spacing was 625mm. As sheathing was used chipboard 12mm thick separated into three panels.

The connection of framing elements was made of G 5/150 nails by two fasteners on each node. The sheathing-to-framing connections were made of G 2,7/65 nails. The fasteners spacing were 50mm on the distance of 1m from the edge of specimen as well 100mm in the middle. The spacing of fasteners connecting sheathing to perimeter beam was 150mm.

During experimental test observed that sheathing is cooperating with framing in wider range then in wall elements. This is due to greater number of sheathing-to-framing fasteners and hence the greater stiffness of floor elements.

The stiffness of floors on low level of external load is very high, so nonlinear behavior of elements is not clearly visible as in case of wall elements.

Load distribution

Light wood-frame buildings are made of structural elements cooperating in carrying the external loads. Stiffness and capacity of whole structure is summation of each elements as walls, floors and roofs.

Walls are carrying the vertical forces from dead and live loads but also working under the lateral load from wind or seismic impacts transferred by floor elements. In both cases wall works as plane-stress element.

Floors also work in two ways. Live load makes the floor behave as plate while under lateral load submitted by perpendicular wall system, works as rigid beam.

The vertical load transmission on individual structural elements depends on how the floor lays on the walls as well the connection type (Lewicki 1979).

Under the lateral load from wind or seismic activities the distribution depends on the stiffness of individual elements. Capacity of single wall is linearly dependent to length. The stiffness change is describe by nonlinear function (Patton et al, 1985). Additionally in stiffness analysis of whole structure is necessary to omit existence of shear walls with length less than 1,22m (White 1995).

Stiffness of wall element is the function of framing, sheathing and nailing stiffness. More fasteners at each panel of sheathing increase the structure stiffness (Dolan 1989), (Baszeń et al., 2000). Increase of studs spacing decrease as well stiffness as the capacity. It depends on using less numbers of fasteners to connect sheathing with framing.

The important to the stiffness is the way the sheathing panels are shaped and nailed. Using continuous panels of sheathing increase overall stiffness of structural element (Dolan 1989), (Baszeń et al., 2000). Similar situation is observed for horizontal orientation of sheathing. The stiffness is 40% higher opposite to vertical orientation (Wolfe 1983). Increasing of the total stiffness is possible by consideration the existence of inner gypsum boards (Rose, Keith, 1996).

Joints

The nonlinear behavior of structural elements of wood-frame buildings is the result of fasteners nonlinearity.

The wall ability to carrying the external loads depends on sheathing-to-framing connection type. The most common fasteners despite high strength have a small cross-sectional area. That make the connection as most vulnerable component of the structure.

The first pay attention to it McCutcheon (1985). During experimental studies was observed the P-D function of fasteners is decisive for resistance to destruction.

The most important for structural element deflection is the destruction type of fasteners. Analyzing the various type of connectors there were obtained the nails are the best. Staples also meet the general criteria of capacity, but do not reach this level of capacity and stiffness as nails properly applied (Zacher, Gray, 1990).

To increase the capacity and stiffness of walls the glued connections are applied. This type of connection decrease flexibility of joints especially at destruction level of loads. Using glued connection with much higher capacity than traditionally nailed joints causes that nails serve as bonding until the adhesive reaches it's full capacity (Dolan, White 1992).

Destruction of joint could take different form. It may involve the bending of the fastener and pulling it out of framing or rely on sheathing's cut by nails as well as panel damage at the corners (Johnson 1997), (Heine, 1997), (Salenikovich 2000), (Baszeń 2004). The way the structure is loaded also affect on the joints destruction. Static loads cause damage by peeling sheathing of the wood frame and pulling out nails when dynamic load causes the joint damage by breaking the nails (Dinehart, Shenton, 1998).

Connection of two walls as well wall to floor is the most sensitive nodes of wood-frame building. Behavior of this kind of joints determine the behavior of whole building providing distribution of internal forces at individual elements and impact on overall building stiffness. Inadequate stiffness of the node despite the bearing capacity of structural elements could lead to disaster. Therefore most important is to determine the stiffness of this kind of nodes and develop an accurate model of its work.

The series of experimental studies of the joints to assess its stiffness was launched at BUT. In the first series focuses on the analysis of stud-to-beam connection behavior to calculate the flexibility of the joint (Fig. 4a). The next series focuses on connections of elements of two walls and floor (Fig. 4b). Future test will define the stiffness and flexibility of various types of connections in wood-frame buildings.



Fig. 4. Research scheme: a) stud-to-bottom beam connection, b) joists-to-walls connection

Building

Staring from 50's of last century the wide experimental studies of wood-frame buildings was carried out. Because of high cost the studies was provided only at limited scope so the results were not properly verified.

One of the first test was the experiment provided in Canada on one-story, basementless house with dimension 7,3x11m (Dorey, Schriever, 1957). The exterior sheathing was omitting and replaced by aluminium siding. The building was loaded by load simulating wind and snow. The study led to the conclusion that winds in excess of 90mph causes first cracks, while snow leads to failure occur in some parts of roof at 143% of design snow load.

Another experiment was conducted on full-scale two-story house representative of housing in the United States. The wood-frame structure was 14,3 m long by 7,9m wide (Yokel et al., 1973). Results from the tests of building under simulated wind loads presented that roof diaphragms behaved like a flexible diaphragm in opposite to second floor elements behaved more like a rigid body.

Two-story typical house full tests were conducted in Japan (Sugiyama et al., 1988). The building was 7,3m wide by 10m long. During the test there were examined the influence of wall sheathing around the openings on the racking resistance of the wall as well as the effect of shear walls placed perpendicular to the direction of lateral loading. The researchers observed a little effect of differences in floor diaphragm openings on wall stiffness, whereas the increase of lateral stiffness as the result of addition of calcium silicate sidings to walls parallel to loading.

The next tests focused on the influence of different sheathing materials on stiffness of shear walls as well the effect of horizontal elements on load distribution to the shear walls (Phillip et al., 1993). The tested house was single-story structure with 4,9m wide and 9,8m long. There were observed increase of stiffness due to inner sheathing existence. The distribution of loads on longitudinal walls was greater in case when the floor elements exist opposite to situation the floor element was disassembled.

Analysis of the behavior of building structure resulted as experimental test of two-story wood-frame house (Fig. 5) (Malesza et al., 2002).

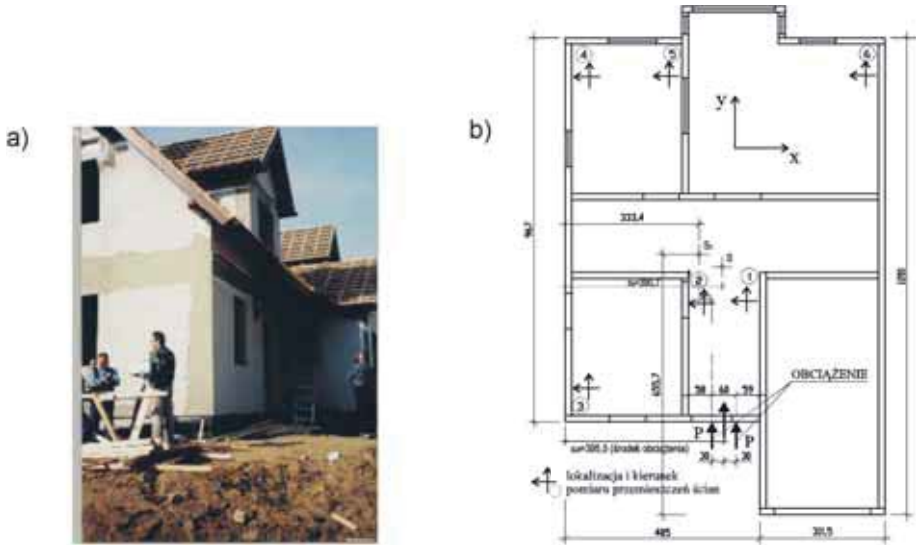


Fig. 5. Tested house (Malesza et al. 2002): a) view, b) plan of ground floor

The wall displacements under the lateral load were recorded. The lateral load simulating wind was applied as two concentrated forces (Fig. 5b). Displacements were observed at six points in longitudinal and perpendicular direction to loads. The load was assumed at design load. Results presented the building had accurate stiffness.

Major importance for wood-frame buildings is its resistance to seismic actions. South-western states of America or the Japanese islands are the places exposed to the risk of earthquakes. Therefore the experimental study was carried out to take into account the seismic response occurred during the earthquake in Kobe (Tanaka et al., 1998) and Southern California (Filiatrault 2010).

Mathematical models and numerical analysis

Wall elements

The high cost of experimental researches resulted in proposals of models describing wall behavior. For simpler cases mathematical equations was used while for more complex problem there were proposed model using finite elements.

First models assumed the fasteners behave linear (Tuomi, McCutcheon, 1978), (Gupta, Kuo, 1985). The models allowed to calculate stiffness or capacity of walls under lateral load. The nonlinear behavior of fasteners was observed during the comparative analysis of results of micro-scale tests and deflection function P-D of previously developed model (McCutecheon 1985).

The limitations of mathematical model made the next models were using finite element method. The rapid development of computer technology caused that large number of unknown is not the problem any more.

In models using finite elements the sheathing is described by plane stress elements, fasteners by system of springs, as well the wooden framing by beam elements (Foschi 1977), (White, Dolan, 1995), (Tarabia, Itani, 1997). More complex models took into account the impact pressure of sheathing panels (Tarabia, Itani, 1997), (Malesza, Miedziałowski, 2003).

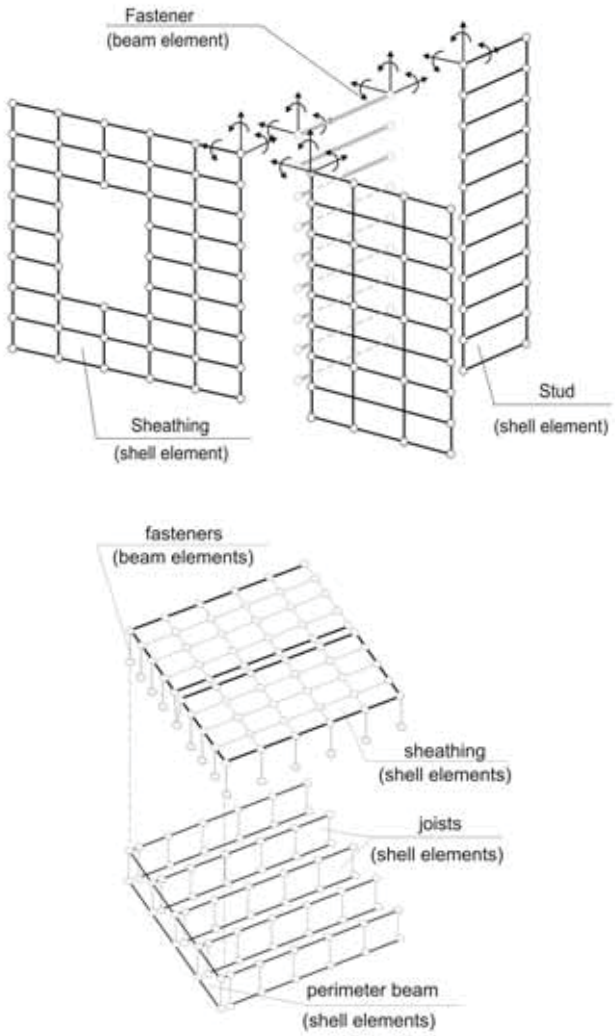


Fig. 6. Finite element model: a) wall element, b) floor element

The completely different approach was proposed in BUT. Timber elements and sheathing were described by shell elements as well the fasteners by the beam elements (Malesza 1997), (Baszeń 2004).

Proposed model was described using finite elements (Fig.6). In contrast to previous models describing fasteners by spring (Foschi 1977), (Dolan, White, 1995), (Tarabia, Itani, 1997), the new models proposed the connector as beam element with six degree of freedom. Slide of connector in the surrounding material influence in a decisive way to it's behavior as well the entire structure.

The main assumption was that only nonlinear elements were sheathing-to-framing connectors. The slide function is described by equation with constants determined from experimental tests.

$$N = (A + B \cdot \delta) \cdot \left[1 - e^{\left(\frac{C}{A} \cdot \delta \right)} \right] \tag{1}$$

This equation was used to determine the replacement stiffness of the beam element EA, EJ, GA, necessary for the element stiffness matrix.

Assuming that material of fastener is isotropic, the replacement modulus of elasticity was obtained from formula:

$$E = \xi \cdot C = \frac{l^3}{12\mathrm{J}} \left[1 + \frac{3}{4} \cdot (1 + v) \alpha \left(\frac{d}{l} \right)^2 \right] \cdot C \tag{2}$$

where:

C – flexibility of connection,
J,l,d – respectively moment of inertia, length, diameter of fastener,
a – shape coefficient, for circular cross-section 10/9,
v – Poisson's ratio.

Flexibility of connectors resulting from P-D curve affect on its nonlinearity. The nonlinearity was described by the change of modulus of elasticity. The nonlinear function was obtained separately for each fastener, as dependance between external load and deflection perpendicular to the fastener axis.

Proposed model was verified by the results obtained from experimental test. As a result of the comparative analysis, it was observed that the proposed model maps with high converge the structure deformation. The experimental and model P-D curves are of similar shape and the values are most similar at the destructive load level. A similar situation also occurred in the case of comparison of internal forces.

Floor elements

The wood-frame floors works in two dimensions. Vertical load is transmitted by sheathing to joists while the lateral load is absorbed directly by the perimeter beam and then transferred to joists which cooperate with sheathing. There is a partial effect of composite structure. Floor works as a T-shaped beam consisting of individual beams with collaborative part of sheathing. Flexibility of wooden joists allows for bi-directional operation and bi-directional bending.

The complex behavior of floor inspired the researchers to create the model describing this work. One of the first model was incorporated into FEAFLO system. The model simplified the structure to system of crossing beams. The composite T-beams was representing joists while perpendicular beams with accurate width was representing sheathing (Thompson et al., 1977)

The next program was FAP using Fourier series to solve problem (Foschi 1982). Similarly FEAFLO so FAP gave results consistent with the values of experimental studies, however, due to time-consuming calculations programs were not suitable for engineering applications.

The simplification was using the beam-to-spring analog model. In proposed model the sheathing was replaced by the single beam based by springs on multi-layer joists. Characteristics of springs was matched with deflection in mid-span of joists (McCutechon 1984). The development of this model allowed for consideration in the calculation appearance of gaps causes discontinuity of sheathing and thereby reducing the flexural stiffness (Friedley et al., 1997).

Another approach was presented in membrane-to-brace replacement method (Kamiya 1990). Model was based on the assumption that floor works as Virendeel truss. The sheathing was replaced by compressed brace elements with stiffness according to sheathing material's properties as well connectors type and spacing. The results taken from model was similar to results calculated using ATC guidelines (1981).

Joints

Fasteners the most nonlinear structural elements of light wood-framed building were not analyzed as separate elements but as part of the general pattern of the walls or floors. The main tendency was to assume that the fasteners as springs.

In one of first models the fasteners were assumed as single spring. The connection between elements of timber frame was described as two degrees of freedom spring, when the sheathing-to-framing joint was described as three degrees of freedom spring (Foschi 1977).

More extended model was presented as the system of three springs (Dolan 1989). The extension of Dolan's model was system of independent springs (White, Dolan 1995). In next model also the system of two independent springs was used but additionally the different stiffness in three dimension was applied (Tarabia, Itani 1997).

Another approach was presented by the model proposed at Bialystok Technical University (Malesza 1997), (Baszeń 2004). In place of springs describing fasteners there were used beam elements with six degrees of freedom. The elements was simulating simple beams flexibly connected in sheathing and framing or both sides in framing. The nonlinearity was assumed only for connection between sheathing and framing.

Buildings

The developed numerical models of wall or floor elements encouraged researchers to develop proposed computational systems into models describing the entire building structure.

One of the first models predicting the behavior of whole building was model proposed by Gupta and Kuo (1987). Otherwise to previous models not including uplifting this model has allowed it. The results taken of the model had good agreement with the results from experimental tests.

Another model proposed was developed evaluate the seismic response of the light wood-frame buildings (Tarabia, Itani, 1997). The main part of the study was observing deformation of the structure and distribution of lateral loads among the shear-walls. The model assumed twofold plate and plane-stress state of structure work, provided that deformation in both states are independent. The sheathing movement was incorporated in the model. To prevent overlap of sheathing panels the contact elements was entered to the system.

Collins et al. (2005) proposed 3D nonlinear FE model of light frame buildings. The model was capable to predict the response of building from the global, as general displacement of building, to individual as behavior of single joint. The predicting ability was verified by experimental researches.

A completely different approach was used in the model proposed by Folz and Filiatrault (2004). The 3D building was degenerated into a 2D planar model using zero-height shear wall spring elements connected between adjacent diaphragms or the foundation. This numerical model has been used in computer program SAWS, which was verified by shake table tests performed on a full-scale two-story wood-frame house.

Most of the buildings constructed in lightweight timber frame technology in the United States was not design according to the earthquake engineering principles. Large window openings and garage doors made the first story soft, what prone the structure to large lateral movements. The need for analyzing the stability and seismic performance of soft-story houses have resulted in proposal 3D model by Pang and Ziaei (2012).

Conclusions

Despite wide range of experimental tests as well numerical analysis behavior of the light-frame wooden structures is still not thoroughly explored. The way its work as the whole structure is result of work of each individual structural elements.

The stiffness of walls, floor as well joints affect the behavior of the whole building. Features as higher stiffness of individual elements as selected joints can significantly affect the model of the building behavior. Knowledge of the model facilitate the designing, allows erecting the buildings much safer and cheaper, due to the optimal selection of the number as well the types of structural elements and connections.

The development of this type of construction, and thus the emergence of new and non-typical structures poses major challenges for designers. Large spans of floor elements, and thus a large cross-sections of the elements make the necessity to determine behavior of the structure, not necessarily working as common objects.

Prefabrication allows to reduction the time of building erection but forces necessity of very careful elements connection at the construction site.

This all makes it necessary to describe the model of the construction behavior what is possible using computational models. The need for proposed model verification necessitates the widest range of experimental tests.

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