

SEARCH OF RATIONAL STRUCTURE SOLUTION OF PREFABRICATED TIMBER HOUSES BEARING PANELS

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ABSTRACT

Design structure variants of glued ribbed panels of prefabricated timber houses with application of chipboard slabs and the results of their research are given. The results of searching of optimum structure solutions and choice of economic materials for panels and technical and economic estimation of their use are given.

Keywords: panels, rib, sheath, testing timber, wood, wood-chipboard slab

1. INTRODUCTION

According to the experience of many countries, progressive development of few-story timber buildings is first of all connected with wide use of panel houses. Thus, it is desirable that the panels were as large as the size of a wall in a house. It decreases the number of junctions in the walls of a house, accelerates mounting and reduces transport expenditures. Besides, the use of these panels allows to fulfill complete furnish during their factory manufacturing and to make interior engineering networks, reducing the expenditures on a construction site during hose erection.

Constructional solution of large-size panels in many cases is taken in the form of ribbed system consisting of bearing ribs and sheathing materials, Figure 1. At a rational choice of materials, sheathing elements may fulfill both protecting and bearing functions, which means to promote rigidity, bearing capacity and reliability of the whole panel. The effect of the latter is especially appreciable if panel sheaths work together with bearing ribs, this can be reached by reliable sticking of panel sheaths and ribs.

Large-size panels consisting of timber bearing ribs and sheathing elements made of wood chipboard slabs are practised in large scale in timber prefabricated house buildings. Application of wood chipboard slabs as sheathing raises manufacturing adaptability, improves functional qualities of panels, reduces labour-consuming character of manufacturing and its cost. Besides, taking into account rather high mechanical properties of wood chipboard slabs in relation to wood, there is an opportunity for more detailed account of its influence on bearing capacity and stiffness of panels. It is especially important for those panels which experience considerable

efforts during house maintenance. As a rule, panels between the floors are more strained as they experience the action of normal and touching stresses at bending by cross loading.

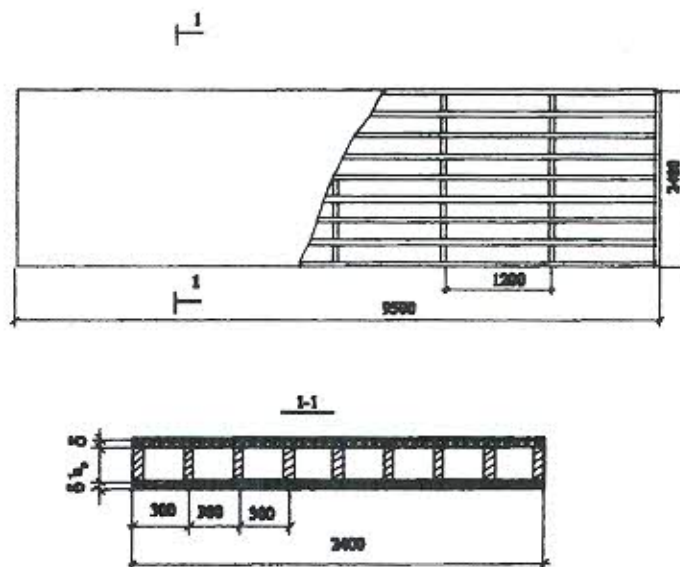


Figure 1 Panel construction

The account of sheaths and ribs cooperation in panels glued together allows to reduce the sizes of their cross-sections considerably, and with other things being equal, to allow greater loading or covering greater spans, that is very important at modern requirements to individual and cottage construction. At the same time there is a problem of optimum designing and searching of rational design solution of such panels connected with determining the ribs member and sizes, sheaths thickness, choice of the most effective materials for ribs and sheaths remaining common requirements to stiffness and reliability of the whole panel. Some results of such research are given below.

Searching of the optimum design solution is carried out for ribbed glued panels by the 2400 × 9500mm size. The panel is used as a floor or prefabricated wooden house with a garret. In a system of the house, the panel works as two span continuous girder with spans $l_1 = 4.90\text{m}$ and $l_2 = 4.35\text{m}$. Continuous loading on the panel are: distributed loading and concentrated forces from the house and concentrated forces from the roof and the garret walls.

While designing of the panel rational structure, such factors as reliability (strength, stiffness and durability), adaptability (possibility of mass line production of panels) and materials consumption are taken into account. Design calculations for ensuring suitable strength, stiffness and reliability were carried out according to the requirements of CN and RII-25-80. (Timber structures Norms of designing) and based on experimental and theoretical results of the authors' experiences.

As the results of natural stuck panels test have shown, coatings and edges work in unison down to panel destruction. It gives basis to calculate stuck panels according to reduced geometrical characteristics.

In the further calculations it is very important to know the reduced moment of inertia. For combined section it is calculated as:

$$J_r = J_{rib} + \left(\frac{E_{sh}}{E_{rib}} \right) J_c = J_{sh} + \eta \cdot J_{sh} ,$$

where J_{rib} = moment of inertia for a rib,

J_{sh} = moment of inertia of a sheathing

E_{rib} = elastic modulus of rib, in Mpa

E_{sh} = elastic modulus of a sheath, in Mpa

$$\eta = \frac{E_{sh}}{E_{rib}}$$

Let's reduce the expression to:

$$J_r = J_{rib} (1+k) \quad (1)$$

Coefficient k shows sheathing share in the whole panel operation. For symmetric section of the panel after some transformations we have

$$k = \eta \frac{3 A_{sh}}{A_{rib}} \left(1 + \frac{\delta}{h_{rib}} \right)^2 \quad (2)$$

where: A_{rib} = cross-section area of all ribs, m^2 ;

A_{sh} = cross-section area of all sheaths, m^2 ;

δ = thickness of a sheath, m;

h_{rib} = height of a rib, m.

The formulas (1) and (2) allow to estimate a degree of influence of sheathings and ribs on the value of limit curving moment $[M]$, perceived by the whole panel, as

$$[M] = \frac{2 J_r \cdot R_{cur}}{H_{rib}} = \frac{2 J_{rib} \cdot R_{cur}}{H_{ed}} (1 + k) \quad (3)$$

$$[M] = \frac{2 J_r \cdot R_{sh}}{(h_{rib} + 2\delta)\eta} = \frac{2 J_{rib} \cdot R_{sh}}{(h_{rib} + 2\delta)\eta} (1 + k) \quad (4)$$

where: R_b = calculated material resistance to rib bending;
 R_{sh} = calculated material resistance to sheath stretching.

The formula (3) is valid for a case when panel destruction is expected on the rib and formula (4) from a disrapture of a stretched sheath.

The analysis of sheaths influence on $[M]$ is fulfilled on panels with sheaths from wood chipboard slabs with thickness $\delta = 10, 13, 16\text{mm}$ and ribs made of surfaced lumbers with cross section $b_r = 44\text{mm}$, $h_r = 120, 144, 168$ and 172mm . The quantity of ribs on the whole breadth of the panel was from 6 to 9. There was a special case when sheaths and ribs were made of wood chipboard slabs (Swedish variant).

In Figure 2 we can see a diagram showing the coefficient k change depending on relation of ribs area to sheaths area. Besides, diagrams can be used for various ribs and sheaths materials having a relative index of elastic moduluses $\eta = 0.1 \dots 0.4$. In particular, for panel with wooden ribs and sheaths made of wood chipboards with continuous characteristics of elastic modulus $\eta = 0.1$, we have diagram 1. In this case sheaths made of wood chipboards can increase bearing capacity and stiffness of the panel to 30-60%. It is easy to note that the role of wood chipboards sheaths in raising of these parameters increases with elastic modulus increase and hence with increase of the sheaths thickness. Thus it is preferable to make sheaths with greater modulus.

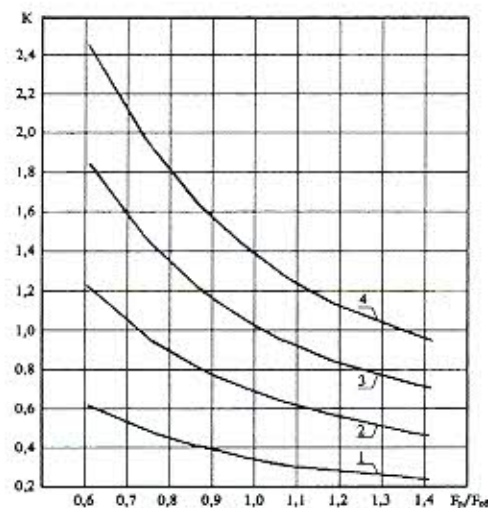


Figure 2 The diagrams of k dependence on A_{rib}/A_{sh} at different E_{sh}/E_r
 1- $E_{sh}/E_r = 0.1$; 2 - $E_{sh}/E_r = 0.2$; 3 - $E_{sh}/E_r = 0.3$; 4 - $E_{sh}/E_r = 0.4$

In Figure 3 the diagram of coefficient k change is given depending on actual parameters of sheaths thickness and ribs section in case they are made of the same materials, in the case of wood chipboard panels. The quantity of ribs in the panel is 9. For these panels, as we can see from the diagrams, the main share in ensuring bearing capacity and stiffness of panels is taken by sheaths, not by ribs, as $k \gg 1$.

Reliability, profitability and panel adaptability to manufacture depends on main bearing ribs structure. We have already discussed the cases when the ribs are made of wood chipboard panels of the thickness of sheaths. However in these cases there are certain restrictions on the value of panels bearing capacity and stiffness, as the lumbers sections are restricted by saw-timber assortment. On the other hand it is not desirable to increase general panel height, as adaptability of manufacturing is disturbed, panel manufacturing and costs increase. Some design variants of bearing ribs are offered, Figure 4.

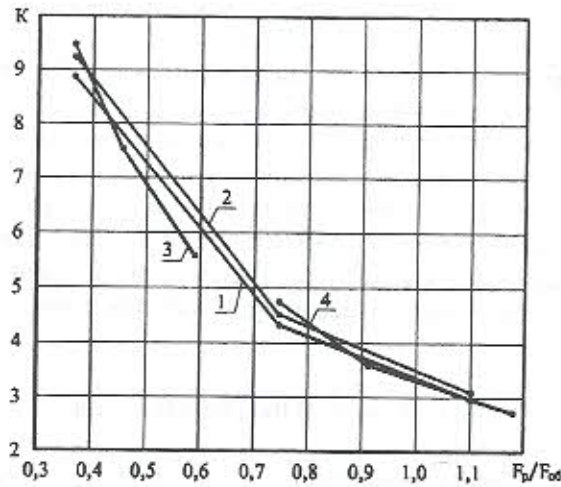


Figure 3 The diagrams of k dependence on A_{rib}/A_{sh} at different δ and δ_{rib}
 1 - $\delta = 10$ ($b_{rib} = 10, 20, 30$); 2 - $\delta = 13$ ($b_{rib} = 13, 26, 39$);
 3 - $b_{rib} = 16$ ($\delta = 10, 13, 16$); $b_{rib} = 32$ ($\delta = 10, 13, 16$)

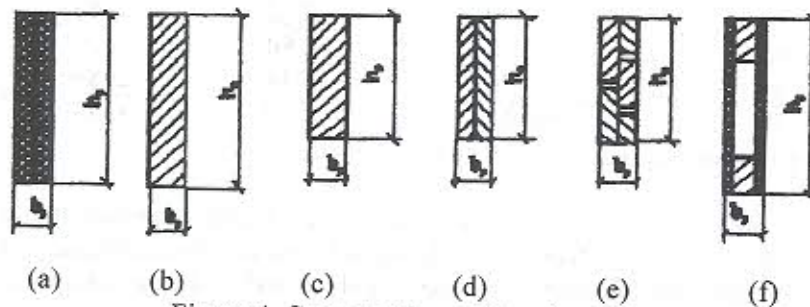


Figure 4 Cross-sections of bearing ribs

The first three types of bearing edges (Figures 4a, b, c) made of strips of wood chipboard slabs (Figure 4a) and internal lumbers (Figures 4b, c) are accepted as basis, others were offered as efficient according to certain parameters. As the ribs in Figure 4d enable to utilize thin saw-timber and the rib in Figure 4e enables to use low quality and small section saw timber, the greatest effect in lowering timber consumption corresponds to a combined rib (Figure 4f).

Besides, ribs (Figures 4e, f) can be made in various heights h_r , irrespective of the sizes of saw-timber assortment, as they are obtained by sawing on many ribbon saws, pasted together to provide larger breadth.

All the offered examples of bearing ribs are adaptable to continuous technology of glued panel manufacturing.

These ribs can be manufactured in wooden house-building plants without any new technological lines. Ribs and panels were manufactured and tested on the Penza prefabricated house-building plant, where several experiments were carried out. All the experimental panels were exposed to building tests up to their destruction in the condition close to natural with the purpose to determine actual stiffness, bearing capacity and reliability. Field tests results of the panels and the offered ribs structures with the sheathing thickness $\delta = 16\text{mm}$ are given in Table 1 (several tests were taken, the dates are average).

All types of panels with ribs illustrated in Figure 4 except the panels with ribs made of wood-chipboard slabs (Figure 4a), as the filed tests results have shown, meet the requirements of reliability, stiffness and are quite adaptable to manufacture in modern plants producing glued panels for prefabricated houses, possess sufficient durability and can be repaired in case of sheathing liftoff or damage during maintenance. Therefore the problem of application of this or that type of panel should be solved in accordance with the presence of certain necessary materials.

Table 1. Results of the panel filed tests

| Type of Panel | Bearing rib structure according to Figure 4 | Maximum bending moment at destructive loading $M_{dis}(\text{kH}\cdot\text{m})$ | Maximum sag at normal loading (mm) | Coefficient of reliability M_{dis}/M_{rat} | Relation $f_{ex}/[f]$ |
|---------------|---|---|------------------------------------|--|-----------------------|
| No. 1 | 4a | 16, 33 | 7, 31 | 0, 65 | 0, 37 |
| No.2 | 4b | 51, 96 | 7, 20 | 2, 10 | 0, 36 |
| No.3 | 4c | 51, 96 | 10, 2 | 2, 60 | 0, 51 |
| No.4 | 4d | 64, 12 | 7, 80 | 2, 50 | 0, 39 |
| No.5 | 4e | 35, 76 | 6, 45 | 2, 85 | 0, 32 |
| No.6 | 4f | 96, 62 | 4, 20 | 3, 85 | 0, 21 |

Note: $[f]$ a limit panel sag according to CN and RII-25-80.

It should be noted that in order to cut the use of saw-timber materials and to increase the panels bearing capacity and stiffness, it is desirable to use combined structure of bearing ribs (Figure 4f), where the belts are made of lumbers, and the walls—of wood-chip board slabs. Box like section meets the requirements of manufacturing technology demands in condition of existing production lines in plants, producing glued panels for prefabricated houses. To get box-like section it is necessary to make a glued sample (by analogy with production of ribbed panel) with the following sawing it into separate elements in according with box-like sizes. The use of double-T section with a single wall gives some saving of wood-chipboard slabs, but is less adaptable for manufacturing, which reduces their efficiency.

Application of box-like ribs allows to lower the use of timber to 60%, besides we need lumbers of available sections (it is possible to use lumbers with section 25×125mm, and 25×150mm.).

Similar panels tests with combined box-like section ribs have shown that destructive loading on the panel exceeds more than 3 times the load being calculated, and exceeds 5.8 times the destructive loading of ribs made of wood-chipboard slabs. Thus, it is possible to regulate the reliability of panels, by applying ribs of different heights.

Table 2 shows the data regarding materials use for bearing ribs of every panel type for 1 house (4 panels) and annual program of a plant (1400 houses). The data are given for the Penza prefabricated house building plant.

For calculating the timber use for ribs made of integral lumber (type 2, 3) additional materials were taken into account for wall conjunction. For ribs type 4, 5 and 6 such junctions are not necessary.

It is easy to note that application of low-grade in bearing ribs of floor panels allows to save 2, 565m² of high-grade timber on each house, at the annual program-1400 houses. (the example of the Penza prefabricated house building plant) gives savings – 3500m³. The savings can be enlarged several times due to application of ribs in all panels of a house, including walling ribs.

Table 2. Materials used for bearing ribs

| Type of Panel | Consumption of materials (m ³) | | | | | |
|---------------|--|---------|---------------------|--------|---------------------|---------|
| | For a panel | | For a house | | Annually | |
| | Wood chipboard slab | Timber | Wood chipboard slab | Timber | Wood chipboard slab | Timber |
| No. 2 | - | 0, 8559 | - | 3, 424 | - | 4733, 6 |
| No.3 | - | 0, 7133 | - | 2, 853 | - | 3934, 2 |
| No.4 | - | 0, 6413 | - | 2, 565 | - | 3591, 0 |
| No.5 | - | 0, 6413 | - | 2, 565 | - | 3591, 0 |
| No.6 | 0, 5417 | 0, 2672 | 2, 167 | 1, 069 | 3033, 8 | 1436, 6 |

Application of box like girders in floor panels allows to save than 2000m³ of wood a year, and besides, this saving can be essentially increased if similar girders are mounted in panels of outside walls. It is advisable to use box-like girders in case of wood shortage.

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