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The Trends of the Optimization for the External Walls of the Dwelling Houses

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Abstract

The factors determined the main technical properties of the external walls - the load-bearing capacity and the heat resistance of the walls used at to day, are analysed. From here the main trends of the development of the wall constructions are determined. They are the optimization for the shape of the wall's load-bearing structure, the use of the high-strength concrete and low density heat insulating materials. So the construction expenses for one unit of the heat resistance of the wall could be minimized. Two structural and technological solutions for realization these trends in Riga Technical University are developed, they are both the prefabricated and the monolithic Thermo-Blocks and Thermo-Panels.

1. Introduction

For single-family housebuilding in Latvia and in other countries with similar climatic condition, in the Nordic Countries, for the external wall construction two principal versions are used:

1) Wood framework structure filled with a heat insulating material – plastic foam or rockwool, covered with vapour insulation and gypsum board from inside and with plastic or wood board facing from outside. These structures have some drawbacks:

- very low fire resistance and therefore the insurance costs are expensive,
- The price of the compression strength of the wood is high – about 6-7 Ls/MPa.m^3, if compare, e.g., with the concrete[*].
- Other drawbacks of the wood, like the weak resistance against roting, cracks, knots, non-homogenity, and big amount of the industrial wastes, for the constructors are well known.
- The rate of the felling of the wood at today is about 4-5 times greater like the rate of the up-growth of the forest in the world, and so the extensive utilization of the wood in construction is very harmful for the generator of the oxygen and for the absorbent of the carbon acid gas, and so the use of the wood in construction cause the shortening of the "planet breath".

2) The use of the masonry walls made of the brick or lightweight blocks with the wet or dry finishing. This type of the external walls also has some drawbacks:

- Due the joints the masonry have a very non-homogenous internal structure and therefore the normative compression strength of the masonry is only 1/5 and less like the strength of the separate masonry components – the stone and the mortar.
- The masonry works till to day haven't mechanized processes and due the expensive handwork the prime cost of the masonry is comparatively high. Therefore the price

[*] At the February 26, 2001 the exchange value is 1 Ls = 1,61 USD.

of the compression strength of the masonry is about 20-26 Ls/MPa.m^3, and it is the most expensive of all load-bearing structural materials.

- The heat conductivity of the masonry isn't sufficient for actual at today heat prices and therefore the masonry walls obligatory must be covered from outside with an additional heat-insulating layer and protected against the environmental actions.
- Due the support reactions of the ceiling and floor structures the compressive stress in the masonry external wall is non-homogeneously distributed. The internal layers of the wall could be overloaded and the external layers always are loaded insufficiently. So the load-bearing capacity of the masonry wall usually isn't utilized completely.

Taking into account the state in the said field of the construction technique, the object of the presented scientific work was a creation of the new solutions for the optimal structures and optimal technological processes for external walls construction. For this goal we must make an optimal choice of the usable materials and optimize the shape of the internal structure in the external wall.

2.Materials

2.1. Load-Bearing Materials

For appraise the economical benefit of the utilization different load-bearing materials, we have proposed a new technical and economical criteria. It is the price of the strength, which is a division of the market price of the material to its compression strength. From this point of view it is evident that the most effective building material working under the compression is the concrete having the lowest prices of the strength, they are in a range from 0.7 till 3.0 Ls/MPa.m^3 depending of the real compression strength. For other popular materials working under compression the prices of the strength always are very higher as it is shown above. From the Latvian concrete market exploration we have stated that with the increasing the concrete compression strength the price of the strength became essential decreased, e.g. for the strength 10MPa it will be about 2.5 Ls/MPa, but for higher concrete classes with the strength 50 MPa it will be 0.7 Ls/MPa only [1]. From here the economical and technical benefit also become obviously – for bearing the same structural load we need more less the cub.meters of the concrete like of the other materials, and with the increasing the strength of the concrete the consumption of these material could be essential decreased. It is a technical and economical benefit. On the other hand - if use the high-strength concrete as a load bearing component in the external wall structure, then with decreasing of the volume of the concrete in the wall volume, we could obtain an increased volume in the thickness of the wall for placing here a more thicker layer of the high effective heat insulation.

2.2. Heat Insulating Materials

The price of the utility also for the heat insulating layer's material of the external walls could be evaluated in similar way. In this case the price of the utility will be the price of the heat resistance of the material, or the market price per one cub.meter multiplied to the heat conductivity. If analyse the Latvian market prices of heat insulating materials, it's easy to notice that the price of the heat resistance will be lower for materials with lower density. So for a very common in Latvia material – the fibrolith having density about 400 kg/m^3 the price of the heat resistance will be 4.9Ls.W/K.m^4, but for the more expensive material – for the mineral wool and foamed polystyrene with the density 30-36 kg/m^3 the price of the heat resistance is less and is about 0.85-0.95 Ls.W/K.m^4.

3. The External Thermo-Walls

In the recent years the monolithic concrete external walls cast in the place with additional heat insulation layer for some public houses in Latvia are built. However, the strength of the used concrete is lower like it is possible at to day. Also the geometry of these concrete load bearing part is choiced the worst – it is a vertical flat slab having the minimal moments of inertia and minimal moments of the resistance of the actual possible. Also here the loads from the floor and ceiling support reactions are eccentric with a deviation from the neutral axis of the slab and so the load-bearing capacity of the concrete isn't completely utilized. Therefore the concrete layer here is heavy and thick – 15 cm and more. Other drawbacks of these technologies are the use of the expensive formwork and the handwork proceses for the following heat insulation work at the facade.

Taking into account the said reasons some new principles for optimal external wall's structures and technology were determined:

1) The two main functions of the external wall, the load bearing and the heat insulation must be very strictly separated. The time of the use the one-layer external walls (brick or block masonry and cobwork) is passed, because they couldn't provide the necessary heat resistance accordingly to the fast raised heat prices, and to the new building codes requirement.

2) The heat insulating material must be selected with the minimal heat conductivity (i.e. with less volume consumption) and with the less price of the heat resistance.

3) For the load-bearing part the more preferable from technical and economical point of view is the concrete, and it must be choiced with the highest strength (as possible for real building condition), i.e. with less price of strength and less amount consumption and having the minimal volume in the wall's thickness.

4) For optimal utilization of the load-bearing material, the concrete, the shape of the structural part's horizontal section must be realized so that provide the maximal possible moments of inertia and maximal moments of the resistance, and, cousecquently, the maximal stability of the wall. It means that the load-bearing part must be not a vertical slab, but made with the counterforts, ribs or made in a shape of a lattice. By use the new technologies of the self-compacted concrete it is easy to perform.

These said principles in the Concrete Mechanics Laboratory of the RTU we have realized in two alternative versions – the prefabricated Thermo-Blocks [2], and the monolithic Thermo-Blocks and Thermo-Panels [3].

3.1. The Prefabricated Thermo-Blocks

This group is a box-type prefabricated concrete elements containing a load-bearing internal vertical slab with three counterforts for increasing the moment of the inertia. As said above, the vertical loads in the external wall always are asymmetric. Therefore the load-bearing part of the block also is asymmetric so that the axis of the inertia of it's asymmetric horizontal section is located in the some vertical flat where the summary eccentric loads are located. If the eccentricity of the section is equal to the eccentricity of the loads actual than a homogenous distribution of the compressive stress and, consequently a full utilization of the load-bearing material could be provided. No continuos cold bridges here are allowed and therefore the counterforts across the wall are interrupted and hiden in the heat insulation. The cavity of the Thermo-Blocks could be filled with plastic foam, mineral wool or other high effective heat insulating material in the process of the fabrication or after the wall is build. The proportions of this Thermo-Blocks are 2:1 (60 x 30 cm), like for bricks, for easy performance the corners and built joints.

3.2. The Monolithic Thermo-Blocks and Panels

They are cast on the building site in special prefabricated formwork made of the heat insulating material – plastic foams or mineral wool. The hollows in the formwork are made in the shape of the optimal and eccentric section of the load bearing part of the wall, like a ribbed slab or a lattice. The lightweight formwork of these blocks is assembled in the shape of the designed wall at the building site, than joint together and filled with high-strength self-compacted concrete. After the hardening of the concrete the permanent formworks stay at the construction and serve as effective heat insulation for the wall. For finishing the heat insulation surfaces different well-known processes could be used.

If use the both versions of Thermo-Blocks for the external wall construction it is easy at the total wall thickness equal 30 cm to obtain the total heat resistance more than 4.0 m^2.K/W, (or the with heat losse $u \leq 0.25$ m^2.K/W). This value meets to the draft of the new Latvian Building Code "Heat Insulation for the External Structures".

If compare the technical and economical indices of the above said traditional wall constructions with the new Thermo-Wall technologies, the building costs per one sq.m. of the wall is approximately this same, while the production of the elements is only handwork, but if the production of the Thermo-Blocks will be industrialized, these costs will be essentially cheapened. However, at the equal costs per one sq.m. at to-day the cost of the utilitar function – the cost of the wall's heat resistance's one unit is about 1.5 ÷ 1.9 times less like for the traditional construction, i.e. the payback time will be essentially shortened.

Conclusions

The potential benefits of the widescale building realization of the Thermo-Blocks construction for external walls are as follows:

1. Structural, because the load-bearing material will be utilized completely and so the external walls will become more warm and more light.
2. Energetical, because the massive load-bearing concrete part of the Thermo-Block will be located at the warm side of the wall and will serve as a heat accumulator for the temperature regime levelling in the room.
3. Economical, because the house-building expenses and also the heating costs could be essentially reduced.

References

[1] Videvud A.Lapsa, Alexander S.Choochooyev, Andrew Ye.Terentyev. The Economical Problems of the Concrete and some Technical Means to solve them. Proceedings of the International Symposium "Prefabrication – Facing the New Century", Helsinki, Finland, October 21-23, 1997, p.46-50.

[2] Latvian patent Nr.12508, June 20, 2000.

[3] Latvian patent Nr.11349, October 20, 1996.

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