COMPLEX RETROFIT OF PREFABRICATED BLOCK OF FLATS – ECONOMIC AND ENVIRONMENTAL ASPECTS

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Summary

This paper is dealing with energy-efficient retrofits of prefabricated houses built in communist era. There are 1.2 million of flats built with such technology in the CR only. Some of the buildings have been partially retrofitted recently but the way of retrofits is not complex enough and in most of the cases it shuts door to the future improvement. Energy conservation measures are commonly only limited to building envelope insulations and window replacement that lead to poor indoor environment quality. A complex retrofit is expensive, furthermore, some technologies that could be beneficial are not ready-for-market yet.

There are two main aspects of the retrofits: economical (investor = occupants) and environmental (state authorities). Any general recommendation for retrofits is not easy to state because of specifics of every each building. Therefore, an approach of statistic analysis based on a parametric model was applied. This model describes set of hypothetical buildings defined by range of parameters and counts specific energy consumption, influence of the energy saving measures, economic assessment and calculation of difference of CO_2 production of every measure applied on the parametrical buildings. Sensitivity analysis of building parameters is very important part of outputs also. Results show that the most important parameter is building geometry whilst impact of the original quality of constructions is rather low.

The ParMo (Parametric Model) can be used as a powerful tool for evaluation of impacts of energy saving measures including economical and environmental assessment.

Keywords: energy efficiency, retrofit, passive house, low-energy, CO2, prefabricated house.

1 Need for “proper” retrofits of prefabricated block of flats

The prefabricated houses are heritage of communist era. They were built for a limited lifetime of 30 – 40 years. Nowadays, many of them are older than was primarily intended. This is very serious situation because about 30 % of Czech people live in this type of houses. However the prefab houses are on the end of their intended lifetime their physical condition is not actually in such bad shape. It is now assumed that such buildings could serve for more than 100 years after a proper retrofit will be made.

The “proper” retrofit is a theoretical way how to fulfill the following requirements:

- Structures and HVAC functions renewing
- Energy savings
- Quality of indoor environment
- Acceptable investment costs
- Acceptable economy

There is one more specific requirement for domestic retrofit: occupants of the retrofitted building are strongly against any moving during the construction work.

- The works must be carried out in occupied buildings only.

Obviously, the ultimate proper retrofit is difficult to reach. In a real life, the result of retrofit is product of negotiation between occupants (investors) and contractors. The biggest problem is an internal negotiation among investors.

The result of such situation is way from optimal solutions, rather partial than complex reconstructions are made. Moreover such ways of retrofits close the door to the future improvement. A use of suboptimal thickness of thermal insulation is a typical example. A price of insulation is only a small part of the total investment costs but the final effect is adequate to thickness of the applied insulation. If the suboptimal insulation is used, the potential of savings is then not utilized. Furthermore, addition of another layer of insulation in the next years is hardly conceivable.

The research task “Complex Reconstruction of Prefabricated Block of Flats towards Low-Energy Standard” is ran by EkoWATT with a goal to find relationships among energy efficient measures and obstacles for their implementation.

2 The ParMo computing model

2.1 The background – building frameworks, shape and age of buildings

The prefabs were built in specific frameworks. The total number of possible frameworks is about 50 and some of them have locally specific subtypes. The framework defines some attributes of a building, i.e. span, presence of loggie, typical number(s) of floors or type of supporting system. A quality of building envelope (from the energy point of view) is not dependent on the framework but on age of the building. There was one main milestone in the history of technical standards – the requirements of thermal insulation characteristic changed in 1979. The later changes did not touch the prefabs because their era finished with the end of communist hegemony in 1989. Vice versa, we can distinguish two main qualities of building envelopes in the beginning of prefabs’ era in the late 50’s: the worse were made of an improved concrete, and the better of sandwich panels with embedded layer of polystyrene. This is the most important information from the point of view of energy efficiency. The information related to building framework is very poor because the frameworks are like brick-box Lego – there is nothing like typical shape of building. The prefab buildings can be of any geometry without relationship to the specific framework. As we will discuss later, the geometry of the building is the key factor influencing energy demand for heating.

On the other hand, there is one important feature related to the building’s framework – type of sanitary unit. The specific frameworks were fitted with some of sanitary units produced in that time. Unfortunately, the borders of cores’ usage are overlapping the frameworks. The unit type is very important for HVAC retrofit. Some types allow additional application of central ventilation systems some not.

2.2 The Parametric Model as a tool to handle the diversity of prefabs

As mentioned above, the shape and age of building are the key factors for energy needs. There is nothing like "typical" building but there are some dependencies between the specific framework and typical numbers of floors, presence of loggie, etc. The parametrical model was built to analyze influence of various factors to the final energy consumption of the building.

The parametric model does not work with specific measurements of buildings but with input parameters like percentage of glazing, shifts between modules of a building, number of floors, etc. There are about 40 input parameters together including HVAC description, factors concerning DHW preparation, ventilation, etc. Each input parameter has its range of values and a distribution of probability. There are some limitations for combinations of some parameters, for example some types of houses cannot have windows on side walls, etc.

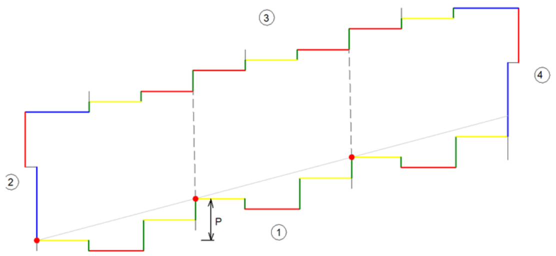

Fig. 1 Parametrical model geometrical conception scheme.

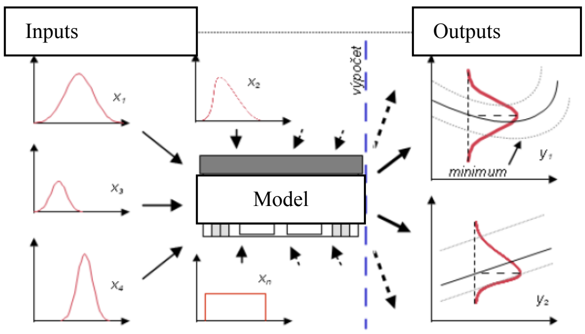

Fig. 2 Calculation model

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The distributions of the values of the input parameters were based on preliminary analyses, calculations, simulations and experiments.

2.2.1 "Virtual city" calculation

ParMo is a calculator of the energy demands of the set of virtual buildings with semi-random attributes. The basic number of buildings in the set is 10 000. Energy demands are calculated in accordance with standard approaches: TNI 730330 for comparison of energy standards, EN 13790 for real boundary conditions or PHPP for passive buildings calculation.

A sensitivity analysis of the outputs shows the partial importance of the specific inputs.

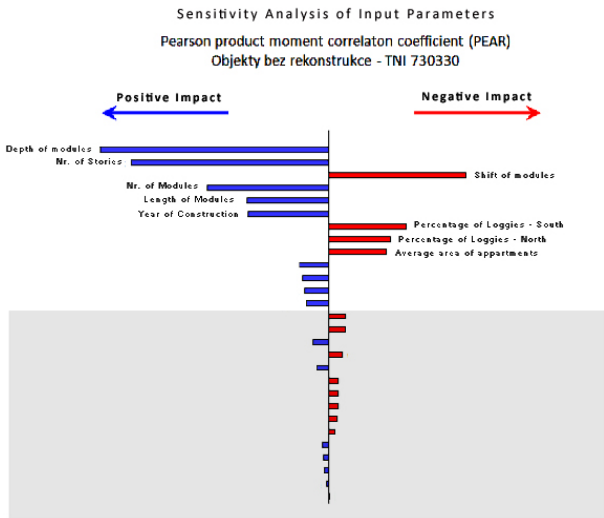

Fig. 3 Sensitivity analysis – non-retrofitted house

As shown on the picture, the geometry of the building is the most important factor for final specific energy need.

2.2.2 Energy saving measures

The ParMo allows application of broad set of energy saving measures from additional insulations of the building envelope to measures in HVAC area (ventilation, DHW preparation, changes of heat source, etc). Each of the energy saving measures is described by parameters comparably to the buildings description.

The model calculates energy, economy and environmental evaluation of the measures application. Influence of each of them can be assessed separately or in conjunction with the others.

The following measures were applied in different levels of the complex retrofit:

Tab. 1 Levels of retrofit – measurements included

Code	Measurement / Level of retrofit	Basic 01	Basic 02	Basic 03	Top 01	Top 02	Top 03	Top 04
ST01	Additional thermal insulation of walls 8	x	x	x				
ST04	Additional thermal insulation of walls 20				x	x	x	x
ST18	Additional thermal insulation of window sills + sides of loggie 8 cm	x	x	x	x	x	x	x
ST05	Additional thermal insulation of roofs 10	x	x	x				
ST08	Additional thermal insulation of roofs 21				x	x	x	x
ST17	Additional thermal insulation of technical floor ceiling 10 cm	x	x	x	x	x	x	x
ST22	Windows, triple glazing, U=0,7 (+ ST27)				x	x	x	x
ST24	Windows, double glazing, U=1,3 (+ ST29)	x	x	x				
VĚ05	Ventilation with local heat recovery				x	x	x	x
TV01	Local heat recovery in baths					x	x	x
TV03	Insulation of DHW circulation piping					x	x	x
ZD00	Original heat source (central distribution)	x			x			
ZD02	Heat pump air-water (electricity powered)			x			x	x
ZD03	Central gas boiler		x			x		
PV01	Photovoltaic panels on roofs (if possible)							x
PV03	Photovoltaic panels on loggie (if possible)							x
PV04	Photovoltaic panels on sunshades (if possible)							x
PV05	Photovoltaic panels on walls (if possible)							x

2.2.3 Statistic way of results presentation

The results can be presented as histograms that are the best way in regard of representation the results for the whole set of 10,000 buildings. Following pictures show the possible results.

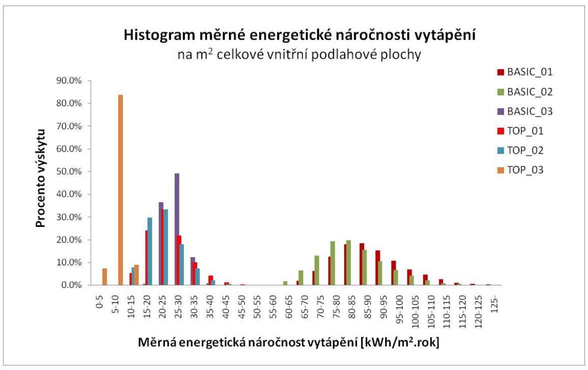

Fig. 4 Specific energy demand for heating for a reference condition and a complex retrofit (200 mm of additional insulation, ventilation with heat recovery).

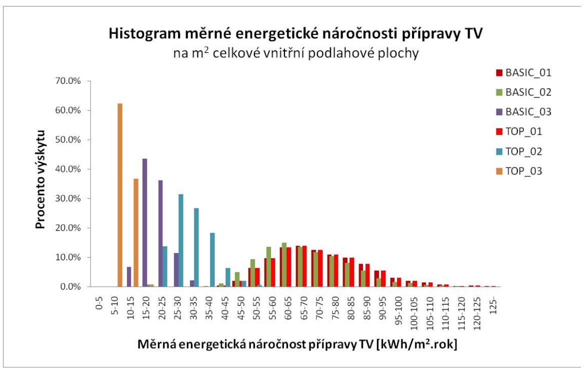

Fig. 5 Specific energy demand for DHW preparation for different energy savings solutions.

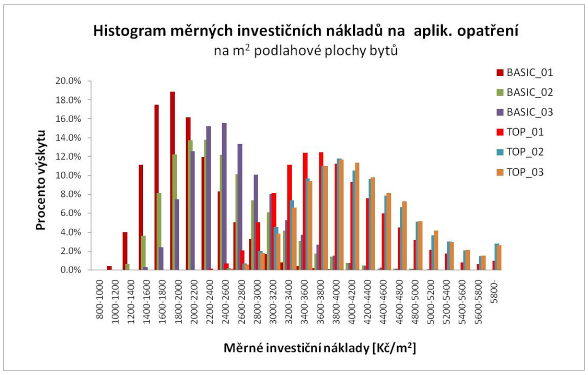

Fig. 6 Specific investment costs per m2 of floor area for different levels of retrofits.

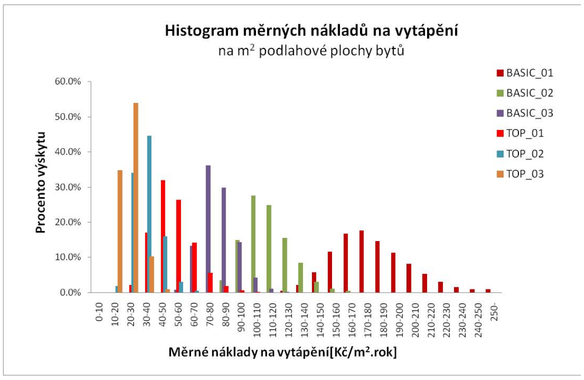

Fig. 7 Specific costs for heating per m2 of floor area for different levels of retrofits.

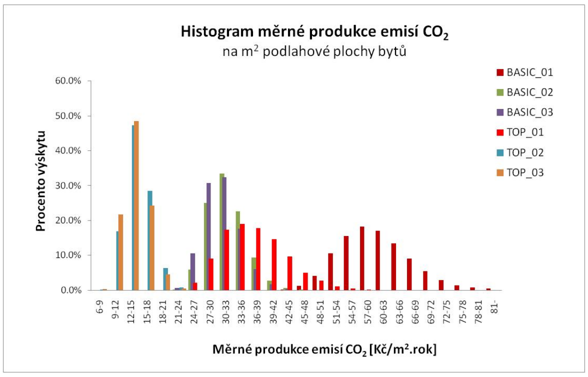

Fig. 8 Specific production of CO2 per m2 of floor area for different levels of retrofits.

Comparing the graphs above, we can imply the possibility of complex retrofit of prefabs to the passive standard in most cases. The investments costs are double to triple higher in comparison with standard low-cost reconstruction.

There are many other possible graphs that could be produced using ParMo including environmental indicators, economic evaluations like payback period, net present value, etc. for any combination of measures. The range of buildings can be filtered for obtaining the results for any more specific set of buildings.

3 Conclusions

The traditional sorting of the prefabs according to the building frameworks is not useable for their energy intensity evaluation. The most important factor is the shape of the building and its age.

ParMo is a powerful tool for statistic evaluation of impacts of energy saving measures application.

There is a real possibility to get the most of prefabs to the passive or at least low-energy standards. The investment costs for such reconstruction are 2 – 3 times higher than the usual reconstruction is.

The most important barrier to the retrofits is non-agreement of occupants of the house.

References

[1] Hojer, O., Jordán, F., Kotek, P., Vogel, P. (2008) Použití metody analýzy nejistoty a citlivostní analýzy na různé typy softwarů stanovujících roční spotřebu energie In: Simulace budov a techniky prostředí. Praha: IBPSA-CZ, s. 127-131. ISBN 978-80-254-3373-7., 2008

[2] Beranovský, J., (2008): Hybridní větrání a rekuperace v panelových domech. Seminář Nejnovější trendy v energeticky vědomé rekonstrukci panelových domů. Praha 12. 12. 2008.

[3] Vogel, P. (2008): Vliv úsporných opatření na energetickou náročnost Panelových budov. Seminář Nejnovější trendy v energeticky vědomé rekonstrukci panelových domů. Praha 12. 12. 2008.

[4] Macholda, F. (2008): Energetické hodnocení domu, rozdíly jednotlivých bytů a rozdělení nákladů na vytápění. Seminář Nejnovější trendy v energeticky vědomé rekonstrukci panelových domů. Praha 12. 12. 2008.

[5] Kotek, P. (2008): Způsoby zjišťování energetického chování domu. Seminář Nejnovější trendy v energeticky vědomé rekonstrukci panelových domů. Praha 12. 12. 2008.

[6] Honzík, M. (2006): Faktory ovlivňující energetickou náročnost ekonomiky. Písemná práce ke státní doktorské zkoušce. ČVUT, Praha.

[7] Maria Eugenia´ Captivo (2007): From Practice to Methodological Issues in DSS for LocationProblems. Conference Proceedings EURO 22, Praha.

[8] Kol. autorů, (2004): SimLab Version 2.2. 2004. Simulation Environment for uncertainty and sensitivity analysis, developed by the Joint Research Centre of the European commission. <http://simlab.jrc.cec.eu.int/>. – freeware

[9] Petráš, D. a kolektiv, (2006) Vytápění rodinných a bytových domů

[10] Kotek, P.: Metoda MonteCarlo jako nástroj optimalizace energetické náročnosti budov. Disertační práce. ČVUT v Praze, Fakulta stavební. březen 2008

[11] Anonymus, (2001): Komplexní regenerace panelových domů. Informační centrum ČKAIT. Ministerstvo průmyslu a obchodu ČR sekce stavebnictví

[12] Projekt SOLANOVA - Building for Our Future, http://www.solanova.eu/, 2006.

[13] Program Panel, Příloha 1: Seznam typizovaných konstrukčních soustav, dostupné ze http://www.sfrb.cz/file/40.