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ЗМІНИ НАПРУЖЕНОГО СТАНУ ОГОРОДЖУВАЛЬНИХ ПАНЕЛЕЙ ПІСЛЯ ДОДАТКОВОГО РЕМОНТНОГО ОБЛИЦЮВАННЯ ФАСАДІВ

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Анотація. Через змінення внутрішньої і особливо зовнішньої температури протягом року, зовнішні шари конструкцій стінових панелей зазнають впливу температурного перепаду. Різниця температур внутрішніх та зовнішніх поверхонь може бути значною. Це явище типове в основному для панелей будинків без утеплювача. Зміни температури призводять безпосередньо до змін у структурі матеріалу, що супроводжуються тріщинами в стиках між панелями. У ході реконструкції панелей будинків виконується достатньо затратний ремонт тріщин та монтаж облицювання. Облицювання саме по собі значно зменшує температурний перепад, структурні зміни і тріщини між панелями. Отже, облицювання може розглядатись як частина відбудовних робіт, проте питання необхідності ремонту тріщин залишається актуальним.

Ключові слова: тріщини, панелі будинків, температурний перепад, облицювання, об’ємні зміни.

ИЗМЕНЕНИЯ НАПРЯЖЕННОГО СОСТОЯНИЯ ОГРАЖДАЮЩИХ ПАНЕЛЕЙ ПОСЛЕ ДОПОЛНИТЕЛЬНОЙ РЕМОНТНОЙ ОБЛИЦОВКИ ФАСАДОВ

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Аннотация. Из-за изменений внутренней и особенно внешней температуры в течение года наружные слои конструкции стеновых панелей испытывают воздействие температурного перепада. Разница температур внутренних и внешних поверхностей может быть значительной. Это явление типично в основном для панелей зданий без утеплителя. Изменения температуры приводят непосредственно к изменениям в структуре материала, сопровождающихся образованием трещин в стыках между панелями. В процессе реконструкции панелей зданий выполняется дорогостоящий ремонт трещин и монтаж облицовки. Облицовка сама по себе значительно уменьшает температурный перепад, структурные изменения и трещины между панелями. Следовательно, устройство облицовки может рассматриваться как часть восстановительных работ, однако вопрос необходимости заделки трещин остается актуальным.

Ключевые слова: трещины, панели зданий, температурный перепад, облицовка, объемные изменения.

CHANGES IN ENCLOSING PANEL STRESS STATE AFTER AN ADDITIONAL FACADE OVERCLADDING

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Abstract. Because of changes in indoor and, in particular, in outdoor temperatures during a year, external components of a structure undergo a temperature gradient influence. Difference between the temperatures of indoor and outdoor surfaces can be considerable. This phenomenon is mainly typical for panel buildings without covering. Temperature changes result directly in volume changes of components accompanied with cracks in the gaps between the panels. In the process of reconstruction of building panels, there is performed a rather costly filling of cracks and mounting of overcladding. The overcladding itself considerably reduces thermal gradient, volume changes, and cracks between the panels. Therefore, the overcladding can be regarded as a part of recovery works, and the question is whether cracks should be filled as well.

Keywords: cracks, panel buildings, thermal gradient, overcladding, volume changes.

Introduction

Indoor and outdoor temperatures during the year load unevenly external components of the structure with a temperature gradient. This results in volume changes in the panel structure. The volume changes depend not only on intensity of thermal loading, but also on sensitivity of the material to thermal changes in terms of structural deformation.

This situation is highly undesirable for instance in original buildings without overcladding. Because of volume changes in the panel structure, cracks appear in gaps between the panels. Since the external panel cannot deform freely, volume changes are accompanied with development of internal forces. If the strength of a material is exceeded, cracks will appear on panel surfaces as well.

The panel buildings are being reconstructed now. Within the reconstruction, cracks are often repaired and additional overcladding is installed. The overcladding reduces the thermal gradient and volume changes. When positive impacts of the thermal cladding are taken into account, repair of cracks can result in financial savings.

A practical calculation of deformations and state of stress of the structure exposed to thermal loading has been carried out using Finite Element Method for an enclosing element of a panel building, G 57 type. The structure has been investigated in four thermal conditions: in the original condition without overcladding and after renovation with overcladding both in winter and summer.

Characteristics of the building and structures under investigation

Deformations and state of stress of the structure exposed to thermal loading have been calculated for an enclosing element of a panel building, G G57 type. The building is located in Ostrava-Z6bYeh and was built in 1962 [5]. The building consists of 4 ground floors and 1 underground floor. Central panels that run longitudinally in the floor in the axial distance 3.6 m are main supporting elements. The structural height is 2.85 m in each floor. Vertical and horizontal supporting structures are prefabricated reinforce concrete components with the thickness 200 mm or 150 mm. The thickness of partition wall is 150 mm. The external cladding consists of panels with the thickness of 240 mm. For more details see [4].

The external panel with dimensions of 1800 x 2850 mm and thickness of 240 mm is made from slag pumice concrete [5]. The thickness of the slag pumice concrete component is 210 mm. Both side of the panel are covered with plaster. In the panel, there is a window opening (1500 x 1450 mm). **Fig. 1** shows the geometry and composition of the panel.

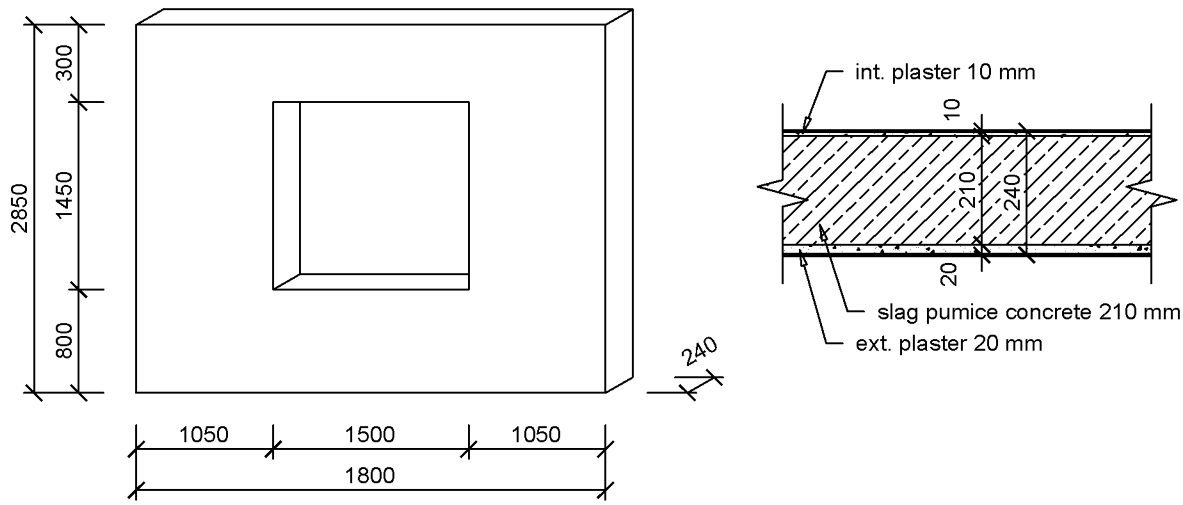

Fig. 1. Geometry and composition of the external panel

Approximately 40 years after the construction, an additional overcladding (extruded polystyrene, thickness: 160 mm [5]) was installed in order to meet requirements in SN 73 0540 [1]. The additional overcladding will considerably improve thermal insulation parameters of the external structure, increase the comfort, and result in heating savings. From the static point of view, the thermal gradient applied on the structure will decrease. All this reduces negative impacts of the volume changes.

Analysis model and loading

The deformation and state of stress of the external panel can be calculated using a FEM model only if parameters of structural materials are known. According to [4], the external panel is made from slag pumice concrete with the density of r = 1400 kg·m^{-3} and average ultimate compression strength of 5.0 MPa. Another important value that needs to be known for the task is a modulus of elasticity of the material used. For light-weight concrete, the formula below [2] should be used:

$$E_b = 0{,}04 \cdot \sqrt{\rho_{bn}^3 \cdot R_{bg}} = 0{,}04 \cdot \sqrt{1400^3 \cdot 5{,}0} = 4685\,\text{MPa} \quad (1)$$

Poisonrs ratio will be n = 0.2. We may consider the linear expansion coefficient to be lower than for standard concrete pursuant to [2], but to be on the safe side, let us assume that the linear expansion coefficient will be $a = 10 \cdot 10^{-6}$.

Analysis model

Because normal forces and bending moments will occur in the structure of the external panel subject to temperature changes, a shell structure will be used for modelling. In fact, the panel consists of three layers with the total thickness of 240 mm **(Fig. 1)**. In the FEM structure model, let us assume for the sake of simplification that there is an only one layer from slag pumice concrete with the constant thickness of 240 mm. In terms of technical accuracy, the simplification is not too significant.

Because it is rather difficult to describe the real supporting of the panel in the structure, two limit conditions of the supporting are dealt with. In the first case, it is assumed that the panel moves freely in gaps. Free deformations take place along the panel. In the FEM model, the shell is supported in such a way that displacements in x and y axes as well as rotation along line supports are possible **(Fig. 2a)**. The second case describes a fixed support where displacements in gaps are not possible. The model is supported in such a way that only rotations along line supports are possible. Displacements along the structure are zero in all directions **(Fig. 2b).** The real state is somewhere between

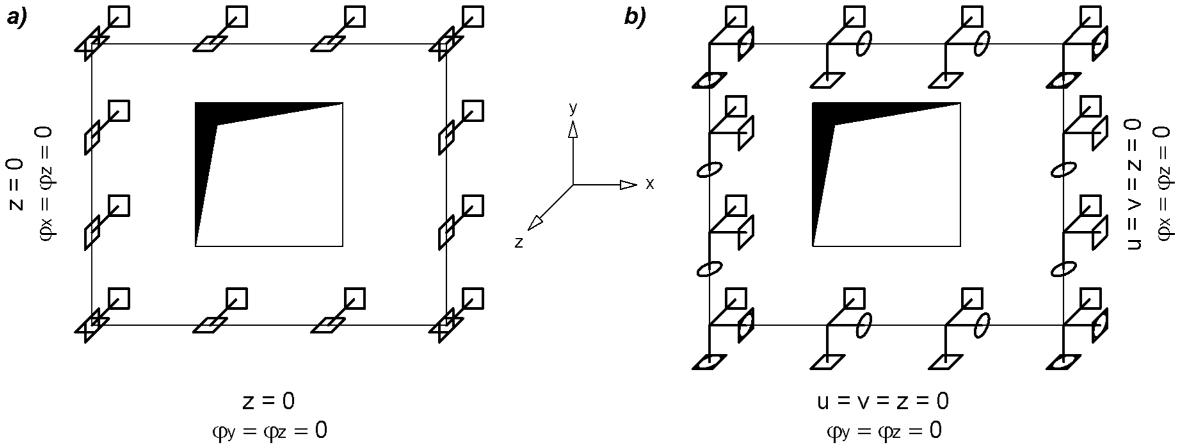

Fig. 1. Calculation model of the external panel: a) free displacements b) bound displacements

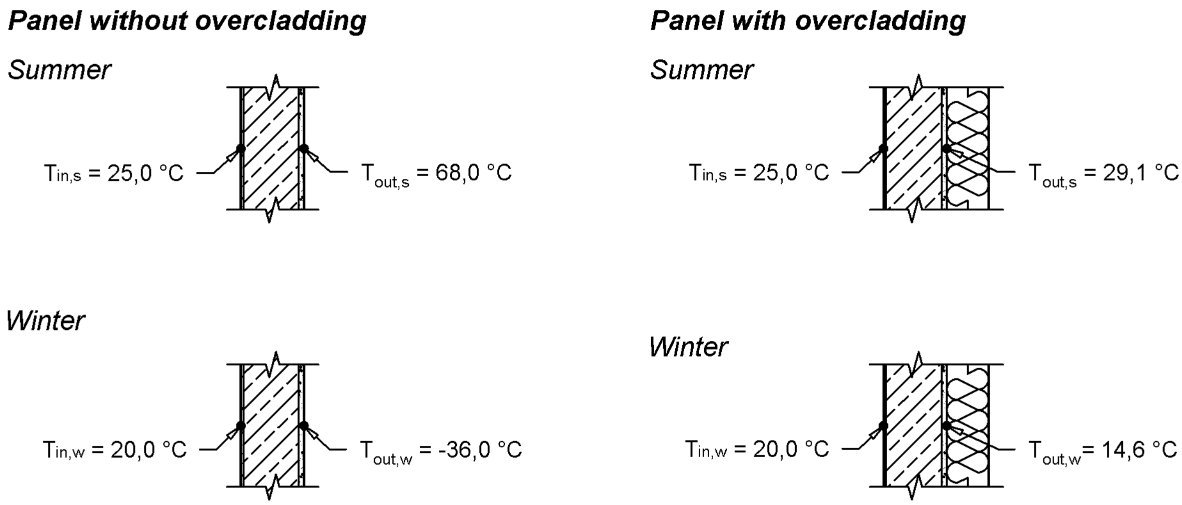

Fig. 3. Thermal parameters of the structure.

these two limit situations.

Loading of the external panel

The external panel of the building is loaded with temperature changes. Such load needs to be determined separately for summer and winter. Pursuant to SN EN 1991-1-5 [3], **Fig. 3** shows extreme temperatures for Ostrava, where the building is located. The temperatures are given for the building with and without overcladding.

Uneven increases in temperatures result in deformations and curvature of the external panel structure. For summary see **Table 1**. The table also shows a considerable decrease in the loading intensity after the overcladding is applied.

FEM results of deformation and internal forces

Resulting deformation plays a major role in structures exposed to a thermal gradient. If the deformation is too high, cracks may appear in places where the panels contact each other. The thermal load causes also internal forces to be developed in the structure. Once the strength of the material is exceeded, cracks will appear on the panel surface.

Deformation

As mentioned above, two limit conditions have been solved for the structure supporting. **Table 2** shows maximum deformations in the lower left

Tab. 1. Thermal loads applied on the structure of the external cladding

Deformation load		Panel without overcladding		Panel with overcladding	
		Summer	Winter	Summer	Winter
Deformation	ε_0 [mm/m]	0,365	-0,180	0,171	0,073
Curvature	k [mrad/m]	1,521	-2,333	0,171	-0,225

Tab. 2. Comparison of the displacement of the external panel for different loads

Displacement	Panel without overcladding			Panel with overcladding			Total decrease [%]
	Summer	Winter	Δ	Summer	Winter	Δ	
u_x [mm]	+ 0,71	- 0,34	1,05	+ 0,32	+ 0,14	0,18	**82,9**
u_y [mm]	+ 0,37	- 0,18	0,55	+ 0,20	+ 0,08	0,12	**78,2**

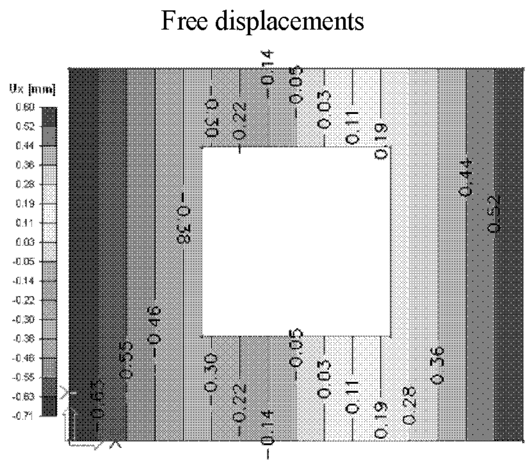

Fig. 4. Displacement of the panel without overcladding in summer - direction: u_x

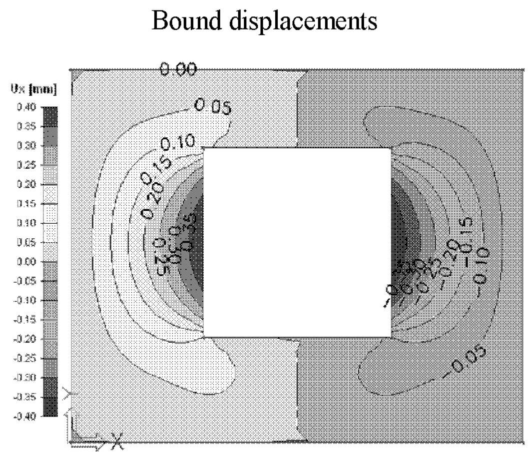

Fig. 5. Displacement of the panel without overcladding in summer - direction: u_x

corner of the panel for specific thermal conditions. **Fig. 4** and **Fig. 5** show the distribution of shift u_x for the both cases. The distribution of the shift u_y is very similar. The real shifts of the structure will be located somewhere between the limit conditions.

Main normal forces

In case of free displacements along the perimeter of the shell, normal forces will not appear. If the structure is supported along the perimeter, the normal forces will be as in Fig. 6 through Fig. 9, this being the case of winter. The influence of the overcladding is clear from the distribution of main normal forces. The reason is that after the overcladding the panel is loaded with positive deformation, while before the overcladding it was exposed to negative deformation. See Table 1.

Main bending moments

Main bending moments are identical for both cases. Before and after the overcladding, the distribution of bending is very similar to each other. After the overcladding, the main moments will decrease considerably. Therefore, the chart shows moment for the structure without overcladding only. See Fig. 10 and Fig. 11.

Fig. 12 shows distribution of cracks in the real structure of the external panel without overcladding. Cracks appear mostly in places with maximum internal forces. They correlate rather well with the distribution of main moments.

It is clear from Table 2 that after the overcladding, the deformation caused by temperature changes decreased by as much as 80 %. The decrease in deformations is directly related to reduced internal forces.

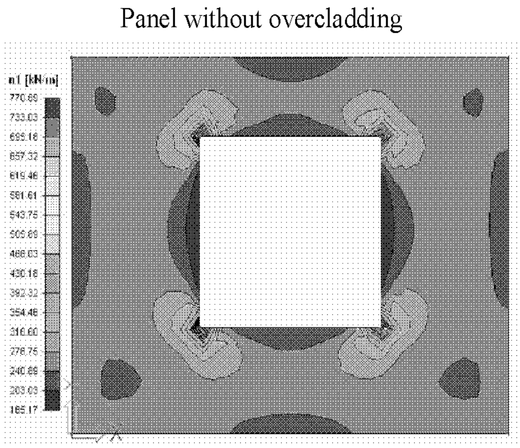

Fig. 6. Main formal forces n1 - structure without overcladding in winter

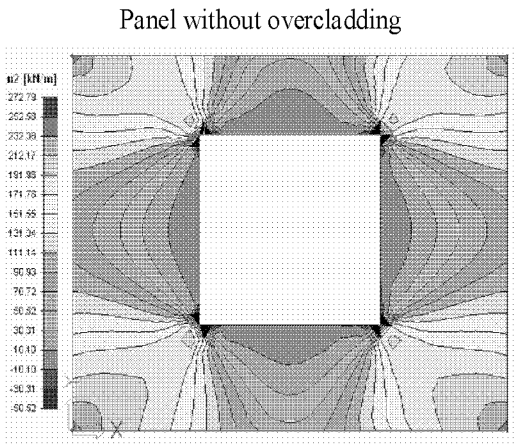

Fig. 7. Main formal forces n2 - structure without overcladding in winter

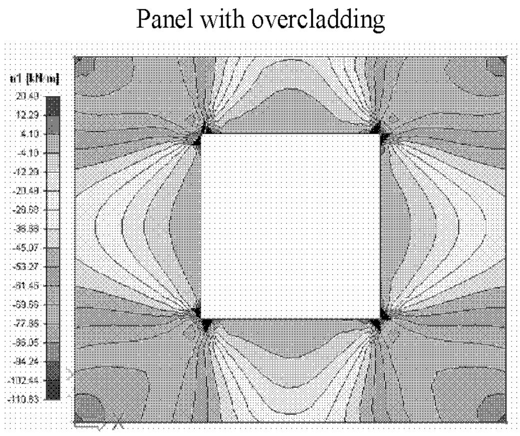

Fig. 8. Main formal forces n1 - structure with overcladding in winter

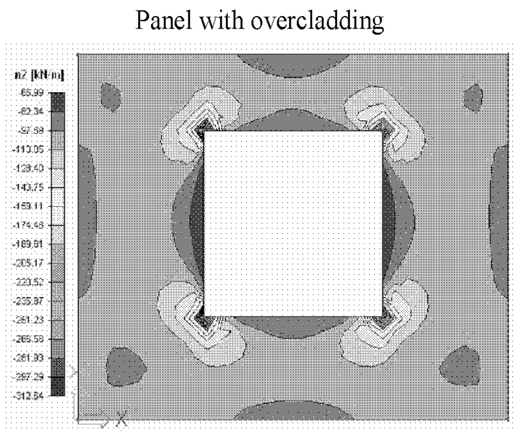

Fig. 9. Main formal forces n2 - structure with overcladding in winter

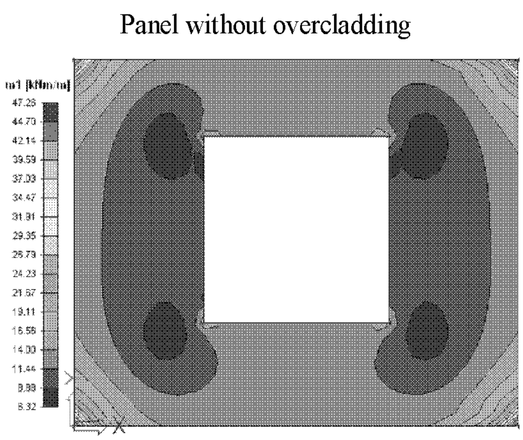

Fig. 10. Main moments m1 - structure without overcladding in winter

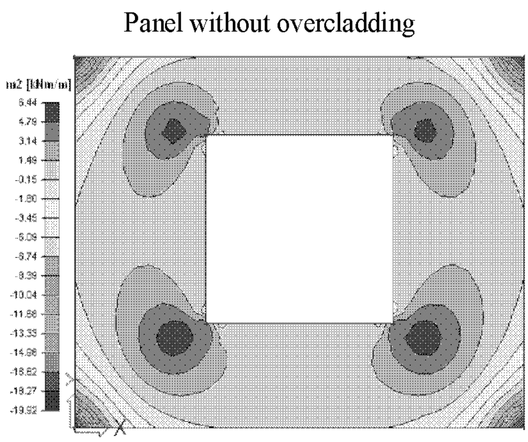

Fig. 11. Main moments m2 - structure without overcladding in winter

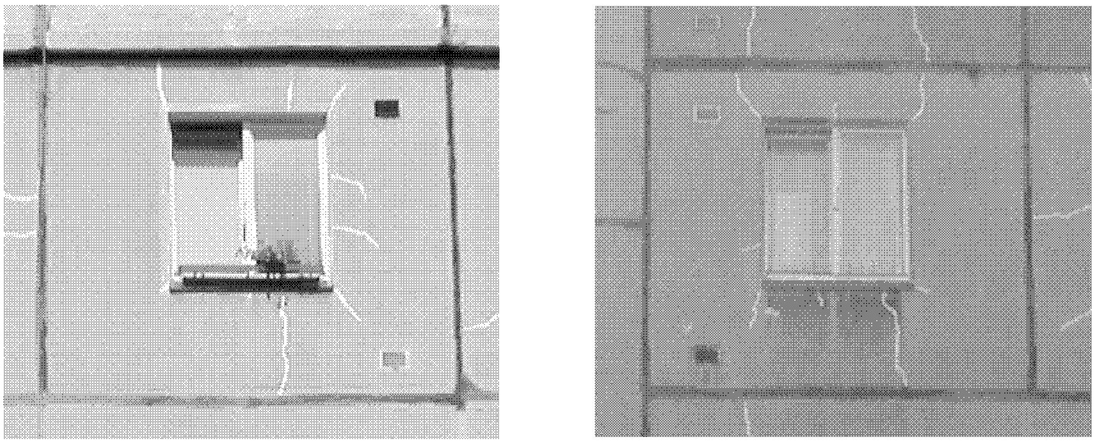

Fig. 12. Distribution of real cracks in the external panel

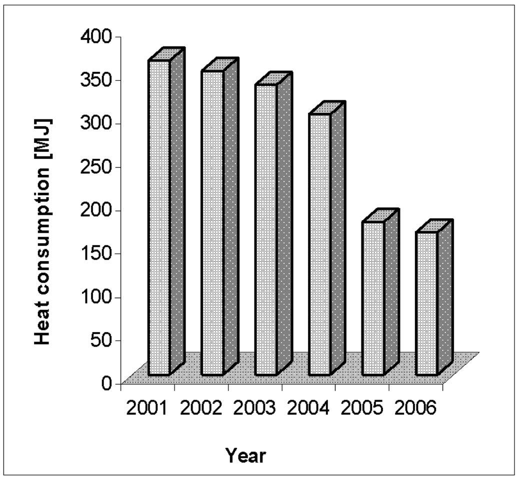

Fig. 13. Heat consumption

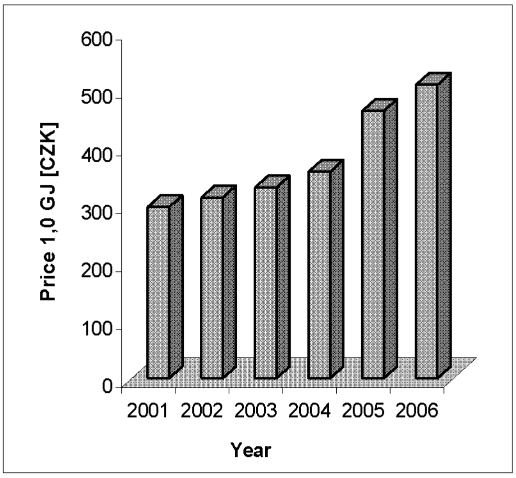

Fig. 14. Heating prices

Comparison of heat consumption for heating purposes

Fig. 13 and **Fig. 14** show positive impacts of the additional overcladding in terms of thermal parameters and consumption of heating energy. The consumption has been calculated from data supplied by a facility manager for flats in the a central doorway. In 2001 and 2002, the consumption was calculated for the entire house. The value for the central doorway was calculated as an average value and can vary slightly from the real value. This is, however, not so important for comparison of heat consumption before and after the overcladding.

Conclusion

The extensive thermal loading of the external panel results in development of considerable deformations and internal forces. The deformation can result in cracks in contact joints of panels. Cracks can also appear in the panel surfaces after the ultimate strength of material is exceeded in consequence of excessive internal thermal forces.

The additional overcladding reduces considerably the thermal loading of the structures as well as the deformation, If cracks are to be repaired in buildings during reconstructions, such repairs are rather expensive. Therefore, it is recommended to take into account positive effects of the overcladding and save funds. Such repairs and renovations can include the additional overcladding.

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