Economical Aspect of Sensitive Flat Roof Renovation

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Abstract. The authors have been working for a long time on the development of sophisticated flat roof renovation that would allow renovation without the need of removing the existing roof layers and so will have a positive environmental impact. The solution is based on the detailed hydrothermal analysis of flat roof and using the potential of the original materials. Subsequently, new layers of the flat roof with optimal parameters for a certain case and possibly other construction modifications are designed. The aim of the development is to create a methodology to achieve equilibrium humidity by perforation of the original waterproof layer. In the paper, the authors describe the key points of this methodology. However, the paper focuses on the economic aspect that this sophisticated renovation brings. Economic evaluation is described through two methodological approaches. The authors compare the developed method with the method involving renovation of flat roofs with the need of removing the existing roof layers. The comparison takes into account the use of different materials for waterproofing and thermal insulation. In order to determine the costs, the authors used the building software to create budgets. The presented economic evaluation confirms the essence of the developed method.

1. Introduction

The authors are working on the development of sophisticated flat roof renovation. In this paper, the authors describe not only the principle of the developed renovation, but also the economic evaluation of the costs of construction modifications. Economic evaluation is described through two methodological approaches. The authors compare the developed method with the method which involves renovation of flat roofs with the need of removing the existing roof layers.

The developing solution is to perforate existing roof layers for draining the moisture content to the new waterproofing layer, which is expansively open to the parapet wall and other subsequent construction. This measure helps to achieve gradually moisture equilibrium and to restore the thermal-technical parameters of the roof deck. In case of the additional layer of thermal insulation, thermal characteristics of the roof are higher.

The aim of the paper is to emphasize the economic aspect of sophisticated renovation. It also points out the ecological impact of this method, which does not include the removing of existing roof layers and also reduces landfilling.
2. Sophisticated renovation of flat roofs
The developed method is based on the detailed analysis of flat roof and this requires a well-developed base. The first step is a roofing inspection. The inspection includes dimensional verification and sampling. Sampling is performed to determine the current state of the flat roof (Figure 1). [1], [2]

![Figure 1. Illustration of sampling](image)

After determining the current state and specifying the materials, moisture detection by impedance defectoscopy follows. In this non-destructive method impedance hygrometers are used. The graphical output is the so-called moisture map, which divides the roof area into parts according to the measured relative humidity. [1], [2]
Determined the appropriate position for sampling is based on the moisture map (Figure 2). Subsequently, the actual moisture content in materials is determined in the laboratory, which is necessary to know for the calculation part of the optimal renovation design. The resulting renovation design involves the design of new layers of the flat roof, especially the new waterproofing layer. Perforating of existing roof layers is based on the building-physical and thermal-technical formulations precisely determined by Spoel [3], Schüle and Reichardt [4]. It also includes the concept of the necessary construction modifications. [1], [2]

3. Methodology
Two implementation methodologies for particular cases of flat roof compared have been designed for this paper. Specifically, the developed method and the method including renovation of flat roofs with the need of removing the existing roof layers. Figure 3 and figure 4 show the new layer in red color and the original layer in black color. [1]
Variants 1a, 2a, 3a and 4a are developed according to the method. Variants 1b, 2b, 3b, and 4b present the method including renovation of flat roofs with the need of removing the existing roof layers.

4. Results and discussions
In order to determine the costs, the authors used the building software to create budgets with price level 2018/2 (table 1, 2). Budgets are calculated for an area of 1.00 m² based on prices from the Czech Republic (€ without VAT). Budgets include working, materials, transporting and waste disposal. [5]

| Table 1. Economic comparison |
|-------------------------------|
|                             | Transporting and | Working and | Working and | Overall |
|                             | waste disposal    | materials - | materials - | costs   |
|                             | (€/m²)³           | waterproofing | thermal      | (€/m²)³ |
| 1a                           | 0.00              | 23.25        | 0.00         | 23.25   |
| 1b                           | 1.05              | 49.70        | 4.55         | 55.30   |
| 2a                           | 0.00              | 23.25        | 7.12         | 30.37   |
| 2b                           | 1.05              | 49.70        | 11.41        | 62.16   |
| 3a                           | 0.00              | 17.83        | 0.00         | 17.83   |
| 3b                           | 1.05              | 44.28        | 4.55         | 49.88   |
| 4a                           | 0.00              | 17.83        | 7.12         | 24.95   |
Table 2. Prices according to roof area

| Variant | 1 m² (€) | 500 m² (€) | 1000 m² (€) | 2000 m² (€) |
|---------|----------|------------|-------------|-------------|
| 1a      | 23.25    | 11625.00   | 23250.00    | 46500.00    |
| 1b      | 55.30    | 27650.00   | 55300.00    | 110600.00   |
| 2a      | 30.37    | 15185.00   | 30370.00    | 60740.00    |
| 2b      | 62.16    | 31080.00   | 62160.00    | 124320.00   |
| 3a      | 17.83    | 8915.00    | 17830.00    | 35660.00    |
| 3b      | 49.88    | 24940.00   | 49880.00    | 99760.00    |
| 4a      | 24.95    | 12475.00   | 24950.00    | 49900.00    |
| 4b      | 56.74    | 28370.00   | 56740.00    | 113480.00   |

*Prices do not include VAT.

The results (Figure 5) clearly show that the developed renovation of flat roofs brings cost savings. However, this method is not suitable for all types of flat roofs. Economy and feasibility depend on the current state of a particular flat roof.

Figure 5. Expression of economic comparison

5. Conclusions

Budgeting software outputs have shown significant cost savings when applying sophisticated renovation. At the same time, the method leads to considerable reducing of ecological loads by landfilling or waste disposal. Nowadays, when the lowest price is the crucial factor, the developed method can play a significant role (table 3).

Table 3. Summary of economic comparison

| Variants “a” (€/m²) | Variants “b” (€/m²) | Difference (€/m²) | Difference (%) |
|---------------------|---------------------|-------------------|---------------|
| 1                   | 23.25               | 55.30             | 32.05         | 57.96         |
| 2                   | 30.37               | 62.16             | 31.79         | 51.14         |
| 3                   | 17.83               | 49.88             | 32.05         | 64.25         |
| 4                   | 24.95               | 56.74             | 31.79         | 56.03         |
Prices do not include VAT.

The issue has been elaborated by the authors on a wider scale as it relates to their current activities. The results obtained are therefore presented briefly in a view of the scope of the paper.

The aim of the whole project is to create a complex methodology enabling a sophisticated approach to the design solution for the repair or renovation of the roof deck without the need for their complete removing.

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