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Modelling Flood Losses to Buildings: Relationship between Room Dimensions and Depth of Flooding

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Abstract. This paper discusses the evaluation of flood losses to buildings using loss curves. The objective of the research was to ascertain whether there is a relationship between the depth of flooding and the amount of unit loss set with regard to the impact of room dimensions. The research was conducted on a sample of 154 model situations for two different room shapes. The results confirm that the depth of flooding, considered in the context of the impact of room dimensions, has an influence over the accuracy of setting the amount of loss, and that the significance of this influence increases with increasing depth. These results can help achieve a more accurate evaluation of flood losses using loss curves or indicators when settling, for example, insurance claims filed in consequence of large-scale flooding.

1. Introduction

Quick and accurate evaluation of flood losses to buildings using loss indicators or loss curves makes it possible to process a large number of insurance claims in a relatively short period of time. It represents an effective method of evaluating the amount of loss to a specific building that allows for a quick payment of the insurance claim and at the same time decreases the costs for the insurance companies. However, the accuracy of this method is questionable, as loss indicators and curves cannot fully replace evaluation using an itemised budget. The accuracy of the outcomes of this method therefore requires special attention.

This paper examines certain factors that have an impact on the accuracy of calculation of flood losses to buildings. More specifically, the objective of this paper is to examine the relationship between the depth of flooding and the dimensions of rooms of various shapes and sizes. By doing so, the paper presents partial outcomes of a long-term research focused on this topic.

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The paper is structured in the following way: first, research background is introduced, it is followed by research methodology. Afterwards, the obtained results are presented and discussed. The conclusion of the paper summarizes the main results of the research and mentions research limitations as well as future research directions.

2. Research background

The topic of the relationship between the geometry of a building and construction costs has already been examined in the current body of knowledge. For example, Cunningham states that building geometry has a major impact on costs, as it is influenced by the size, shape and complexity of the object [1]. A building project should therefore be drafted so as to be cost-effective from the point of view of the investor, using for example indexes evaluating shape-effectiveness of a building [2]. In this respect, the results of Belniak *et al.* show that a 0.1 change in the value of the VOLM index (Volume – block compactness index evaluating building shape) corresponds to a 6% change in constructions costs [3].

It can therefore be assumed that building geometry will also have an impact on the amount of future losses, whether caused by a natural disaster or another factor; this paper examines only flood losses. It is necessary to mention that apart from depth of flooding, losses caused by floods are also influenced by a number of other variables, such as the duration of flood, bear load sub-grade [4], velocity [5], material and structural characteristics of the building and the stability of structures in case of multiple floods [6].

As it was proved during the preceding stage of the research [7], *room dimensions have an impact on the amount of unit loss in relation both to the size of the room and to its shape*; moreover, *the combination of these two factors may in extreme cases have a fundamental impact on the amount of unit loss*. In this respect, it seems desirable to examine the extent to which these relationships have any impact during the modelling of flood losses for different depths of flooding.

3. Research methodology

The preceding stage of research defined building categories [8] in accordance with the use of the buildings (A – houses, B – housing units, C – common and basement areas of apartment buildings; due to structural and material characteristics of the solution, this paper examines only categories A and B), room size groups (altogether 14 groups) [7] and a side ratio (*SR*) indicator [7] defined by the following relationship:

$$SR = \frac{l}{w} \tag{1}$$

with variables *l* and *w* representing room dimensions (*l* = length, *w* = width). This paper compares the outcomes for 2 *SR* values: *SR* = 1 (square-shaped room), *SR* = 0.1 (rectangle-shaped room). The core parameters of the examined sample are listed in table 1.

Table 1. Parameters of the examined set.

Room size group	Area [m^2]	Side dimensions *l*, *w* with side ratio 1.0 [m]	Side dimensions *l*, *w* with side ratio 0.1 [m]	
		l = *w*	*l*	*w*
RG1	4	2.000	0.632	6.325
RG2	6	2.449	0.775	7.746
RG3	8	2.828	0.894	8.944
RG4	10	3.162	1.000	10.000
RG5	12	3.464	1.095	10.954
RG6	14	3.742	1.183	11.832
RG7	16	4.000	1.265	12.649
RG8	18	4.243	1.342	13.416
RG9	20	4.472	1.414	14.142
RG10	22	4.690	1.483	14.832
RG11	24	4.899	1.549	15.492
RG12	26	5.099	1.612	16.125
RG13	28	5.292	1.673	16.733
RG14	30	5.477	1.732	17.321

For $SR = 1$, it holds that $l = w$; for $SR = 0.1$, it holds that $l/w = 0.1$. The following structural and material specifications were set for the examined rooms: vertical structures consist of a masonry wall with plaster and paint, horizontal structures consist of a concrete panel and laminate composite flooring. These specifications are identical to the ones used in the previous research [7].

For the purposes of modelling damage to structures, the parameters of the flood also had to be specified. At this stage of research, the depths of flooding used in the models ranged between 0.00 m and 2.50 m. Other flood factors (duration of flooding, flow velocity, etc.) were not taken into account at this stage. The depth of flooding was recorded for each 250 mm increase in depth; overall, the analysis assessed 154 scenarios for 11 different depths of flooding for a specific *SR* value. The scale of damage to structures can be specified in this context. In the case of floors, the structures in question are the tread layers and baseboards; in the case of walls, they are plasters and paints. Damage to horizontal structures remains constant for various depths of flooding, while damage to vertical structures increases in proportion to the depth of flooding. This stage of research disregards damage to door wings and frames. For the purposes of loss modelling, depth of flooding of 0 m entailed only the damage to horizontal structures, with no damage to vertical structures (disregarding any possible damage to plaster by capillary action).

Afterwards, itemised budgets corresponding to the estimated level of damage were developed for the individual scenarios to set the costs needed for the repair of the damaged structures. For the flooding of masonry walls (vertical areas), the budget includes costs of work related to the removal of plaster, high-pressure cleaning and disinfection of the masonry, manual plastering using lime stucco plaster and final surface treatment using two layers of antimicrobial paint. Flooding of floors (horizontal areas) was modelled specifically for laminate composite flooring. The work included in the budget consists of mounting and removing laminate floating flooring, baseboards and bottom counterbalance layer, just as in [7]. Calculation of costs related to transport of rubble and material on the construction site was added to the work done on both vertical and horizontal structure. Afterwards, unit loss for 1 m^2 of room floor area was calculated from the resulting amount of total loss.

The price of work and materials was calculated using the KROS plus budgeting programme with 17.00 price database [9]. The materials used are priced at the standard level. All prices for work and material are listed without VAT (exchange rate CZK 1 = EUR 0.0365 as of 6 May 2015). In the next step, loss curves for the individual room size groups were created in Excel programme for *SR* = 1 and *SR* = 0.1.

4. Results and discussion

Processing 154 scenarios for the defined *SR* (altogether 308 model situations) resulted in a large data file with information about unit losses per 1 m^2 of floor area. Thanks to a sufficient amount of data, it was possible to represent the data graphically in the form of lines. Altogether, there are 14 lines with each line representing one room size group. Figure 1 shows the amount of unit loss per 1 m^2 in relation to changing depth of flooding for *SR* = *1* (square room). Figure 2 shows the same for *SR* = *0.1*.

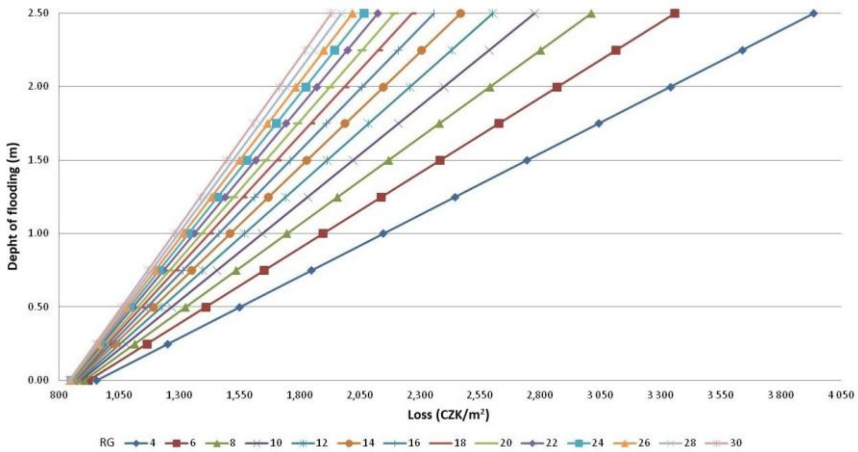

Figure 1. Loss curves for *SR* = 1.

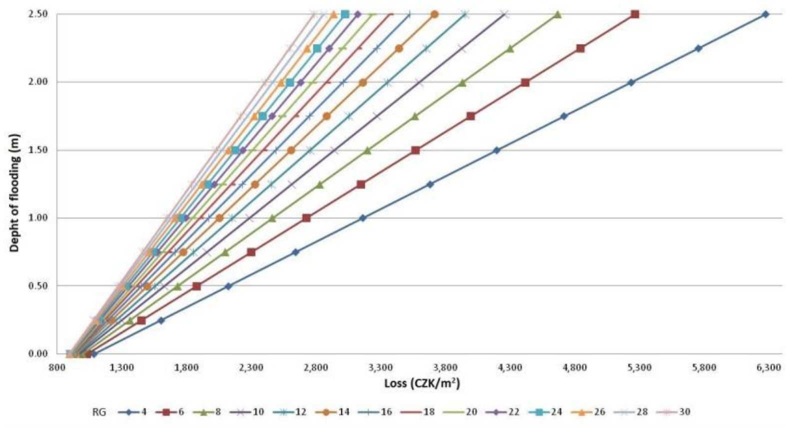

Figure 2. Loss curves for *SR* = 0.1.

Both charts clearly show that the loss per 1 m^2 of floor area increases linearly with the increasing depth of flooding of the room. In general, it holds that the larger the area of the room, the lower the unit loss and vice versa. This dependence arises out of the changing proportion of the amount of loss resulting from damage to horizontal and vertical structures in the total loss. The closer *RS* is to 1, the lower the unit loss and vice versa – the larger the difference between the length and the width of the room, the higher the value of the unit loss. This dependence is valid regardless of the size of the room. The reason is a longer room circumference related to the lower side ratio value; the primary consequence of this is an increase in the areal extent of damage to vertical structures (plaster, paint). These connections were proved at the previous stage of research and are confirmed at this stage [7].

It is interesting to note that an increase in the depth of flooding corresponds with a more profound difference between unit losses, for example, when comparing different *RG* or *RS*. This is clearly presented in table 2.

Table 2. Difference in unit loss per m^2: RS/RG/depth of flooding.

Room size group	Room area [m^2]	Side ratio	Depth [m]	Unit loss [CZK/m^2]	Comparison base	Increase in unit loss value
RG1	4	1.0	0.0	954.879	Base 1	100
RG1	4	1.0	2.5	3938.731	Base 2	100
RG1	4	0.1	0.0	1084.532	Base 1	114
RG1	4	0.1	2.5	6274.205	Base 2	159
RG14	30	1.0	0.0	843.536	Base 3	100
RG14	30	1.0	2.5	1933.085	Base 4	100
RG14	30	0.1	0.0	890.879	Base 3	106
RG14	30	0.1	2.5	2785.880	Base 4	144

Table 2 shows that the significance of the relative difference of unit loss per m^2 for different *RS* (1 m and 0.1 m) within one room size group increases with increasing depth of flooding. Specifically, the amount of unit loss for *RG1* and depth of flooding of 0 m is 14% higher for *RS* = 0.1 m than for *RS* = 1 m. At the same time, the amount of unit loss for the depth of flooding of 2.5 m is 59% higher for *RS* = 0.1 m than for *RS* = 1 m. This dependence can also be seen in the case of values related to *RG14* as well as for situations when *RS* is constant and *RG* is changing.

It can therefore be concluded that the impact of room dimensions on the amount of unit loss increases in significance with increasing depth of flooding. This is caused by the changing ratio of damage to vertical and horizontal structures.

Future analyses should take into account some of the other factors that have an impact on the amount of flood losses to buildings. Flow velocity might be a suitable choice in this respect, as reported by [10]. Similarly, the authors in [11] confirmed on the case of a 2-storey masonry building with basement that high water flow velocity increases the water damage ratio.

5. Conclusion

This paper focused on the modelling of flood losses to buildings using loss curves. Specifically, its objective was to ascertain whether there is a relationship between the depth of flooding and the amount of unit loss set with regard to the impact of room dimensions. The results proved that the impact of room dimensions on the ability to evaluate the loss with the required accuracy becomes more significant with increasing depth of flooding. In other words, the higher the depth of flooding,

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the greater the inaccuracy in the setting of the unit loss, unless room dimensions are taken into account during the evaluation process.

There are three main limitations to this study that need to me mentioned. First, the research does not take into account other parameters that may influence the amount of unit loss (such as flow velocity or duration of flooding). Second, only the floor and vertical structures of the model rooms were taken into account; doors and windows were not included in the model. Third, the relationships described in this paper are valid for individual (separate) rooms, but not for whole buildings. Therefore, future research should be directed not only to accounting for doors and windows, but also to modelling various material specifications so as to assess the significance of the examined factors on the level of the whole building.

More detailed future research into the use of loss curves and indicators could contribute to a more accurate choice of parameters for loss assessment, which is not only used for settling insurance claims but could also be helpful for the prediction of potential future losses and adjustment of loss rates.

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