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## ASSESSMENT OF UNDERFLOOR VENTILATION OF HISTORIC BUILDINGS USING ANSYS CFX

Concepts of remedial treatments of historic buildings using ventilated floors, with a few exceptions, are with considerable popularity preferred by the representatives of monument protection. The fact that they require small interventions in the masonry is of great benefit for compliance with the methodology of cultural heritage protection, as is the fact that such interventions do not compromise the structural analysis of buildings. These concepts have gained great popularity also because they can be considered kind of a "return" to historical example. With these technologies we return to the methods and principles that the ancient Egyptians were already familiar with. The paradox is that these methods are used for many centuries, until today they are only proposed on the basis of empiricism. There is no proven relationship and calculation nor any literature that would address the airflow in floors, ventilation ducts and galleries around the base building construction. The remaining problem is the draft of air cavities in general. The exact calculation of airflow in the underfloor cavity has not yet been formulated. To assessment the airflow in the air cavity the recently often used CFD simulations can be employed. Using simulation, respective design cycles, which shall be ultimately verified by laboratory experiments and also by in situ measurements, may be accelerated.

**Keywords:** underfloor ventilation, historical buildings, ANSYS CFX

### INTRODUCTION

Historically impressive churches may still be found in various parts of the Slovak Republic. It is often only due to these structures, that we gain valuable insight into historical design and construction of historical buildings in Slovakia. In spite of the fact that such culturally valuable structures deserve proper attention and care, many of them remain forgotten and fall into disrepair [1].

Moisture ingress is amongst the most common problems that affect historic buildings. One of the few options available to prevent the gradual destruction of the interior surface involves the use of natural ventilation in the interior. This non-destructive method is often applied to historical monuments. Fluctuation properties of the environment in naturally ventilated churches are described in studies [2, 3].

This article also divulges another method based on historical examples, by applying underfloor air cavities that promote natural ventilation as a result of external wind effects. Similar design problems and air cavity assessments are described in paper [4].

## 1. UNDERFLOOR VENTILATION

A basic requirement with rising damp is the installation of a retrofitted horizontal damp proofing course with the essential accompanying treatments. Only once the cause of the moisture penetration into the masonry wall has been eliminated, the masonry will dry out. This reduction results from the evaporation of the moisture in the masonry, whereas the speed of evaporation depends on the thickness of the masonry, the degree of salinization and moisture penetration, on the climatic conditions around the facility and the airflow around the wall, as well as the make-up of the wall surface [5].

Maintaining underfloor ventilation (Fig. 1) is an important part of controlling damp, as it allows soil moisture to evaporate beneath the floor and to pass out through the vents in the lower walls. Without this ventilation the moisture “stress” on the walls would be much greater. One of the worst mistakes of renovators is to remove ventilated timber floor and replace it with concrete slab poured on sand or fill. The concrete prevents evaporation and all the soil moisture rising beneath the building is now focused on the walls (Fig. 2) [6].

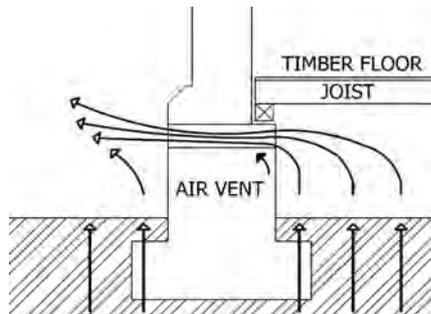


Fig. 1. Well-ventilated underfloor space allows soil moisture to evaporate to the open air [3]

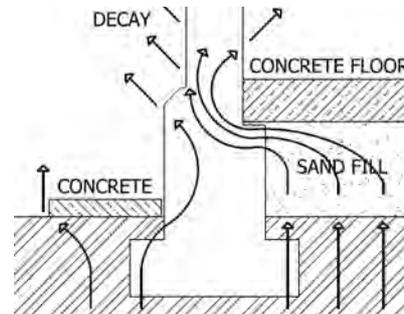


Fig. 2. Concrete slabs prevent evaporation, so soil moisture is forced up the wall [3]

## 2. MODEL EXAMPLE

A historical church, illustrated in (Figs. 3, 4) has been selected as a model example of underfloor ventilated cavities. The geometry and structural composition of the church is typical of many religious buildings scattered throughout the territory of the Slovak Republic.

The air cavity is designed according to empirical principles. The total area of the intake and exhaust openings approximates 1/100th of the ventilated floor space. The cavity has a height of 450 mm (determined by the height of the embankment), a size larger than the recommended minimum of 100 mm. Inlets are designed on windward (north) side, leaving exhaust outlets on the leeward (south) side.

In the event that the interior of the church is artificially heated during the winter, appropriately positioned thermal insulation will be required in accordance

with the requirements of STN 73 0540-2 [7] and calculations determined by the boundary conditions of STN 73 0540-3 [8]. The evaluation of annual energy consumptions according to STN EN ISO 13790/NA [9] procedures and the evaluation of thermal bridges according to EN ISO 10211 [10] are in this case (historic building) inadequate.

### 3. CFD SIMULATION

ANSYS CFX [11] is used to assess the underfloor ventilation model example (Figs. 3, 4). Of the two completed simulations, the first overall geometry of the modeled church ascertains the actual pressure on the walls due to wind effects. Results from the first simulation are applied as boundary conditions, where the geometric model represents the underfloor air cavity.

The overall geometric model of the church is simulated by a wind flow of  $3 \text{ m}\cdot\text{s}^{-1}$  induced at the north face, which increases with height. The modeling process is realized due to changes in pressure along the length and height of the windward and leeward sides. However, modeling an air flow with constant speed of  $3 \text{ m}\cdot\text{s}^{-1}$  for each inlet (in second simulation), is deemed inappropriate.

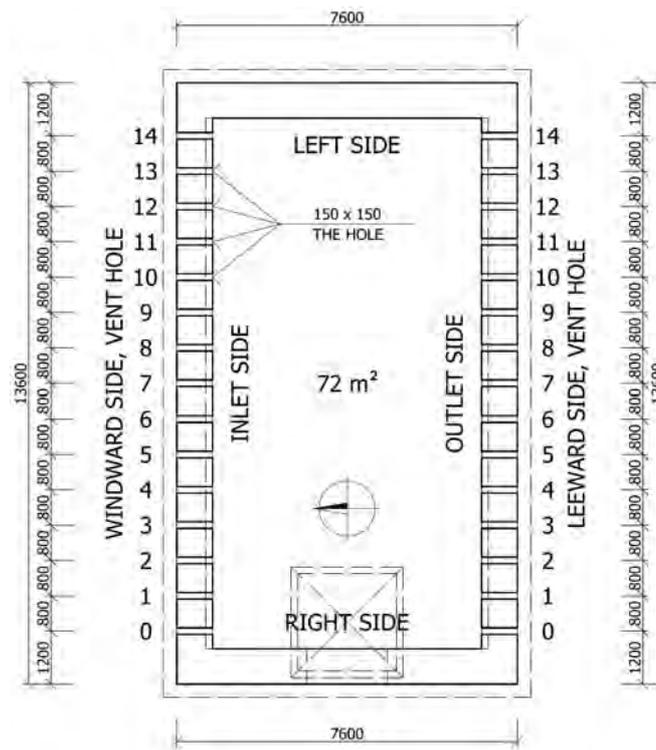


Fig. 3. Ground plane of the church

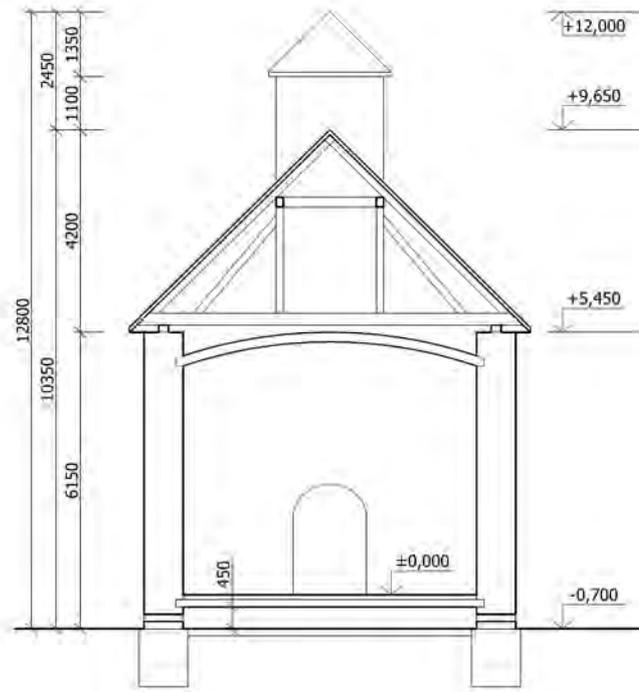


Fig. 4. Cross-section of the church

Figure 5 illustrates the pressure induced on the windward (north) side of the church. It is visible that wall pressure waves are symmetrical, changing in length and height according to the wall. Inlet pressure increases towards the centre of the ventilation's inlets.

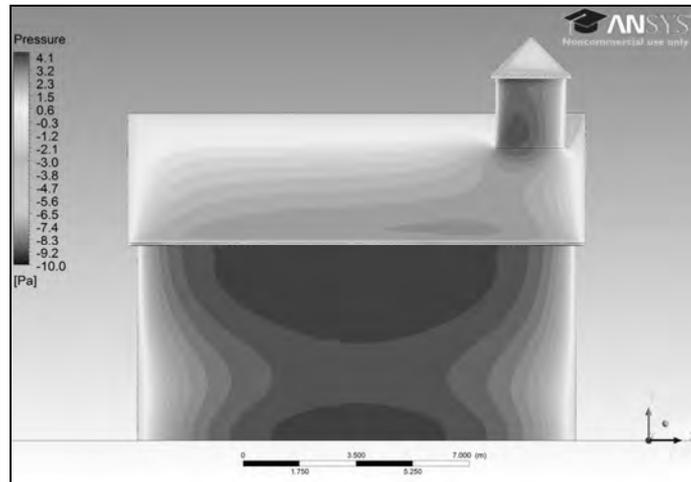


Fig. 5. Pressures on the windward side

Figure 6 reveals the air suction on the leeward (south) side. The pressure wave is greatly influenced by the church tower. Here, air suction is asymmetric at the opening.

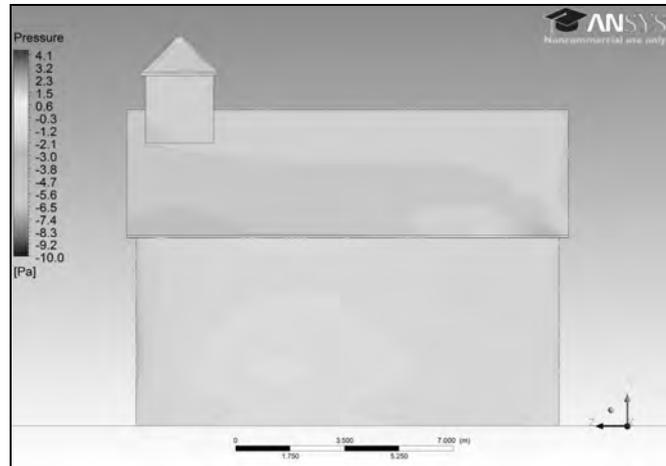


Fig. 6. Pressures on the leeward side

The designation of input boundary conditions for the second simulation (independent cavity) requires the logging of exact pressure values at the intake and exhaust openings. Curves are shown in Figure 7.

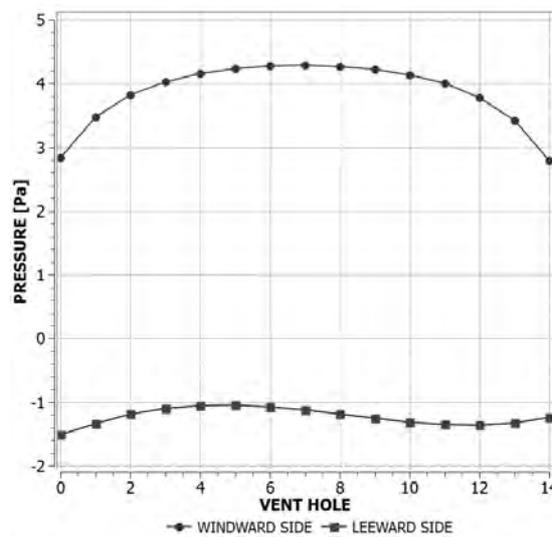


Fig. 7. Pressures on holes

Secondly, the geometry of the underfloor air cavity with the intake and exhaust openings is independently modeled. After deducing the windward and leeward

pressures (Fig. 7) individual values are entered as input boundary conditions (input, output) for the modeled cavity.

In Figure 8 an air velocity is produced along the longitudinal section of the cavity axis. From these results it is obvious that the airstream flows from the side of the openings towards the centre of the cavity.

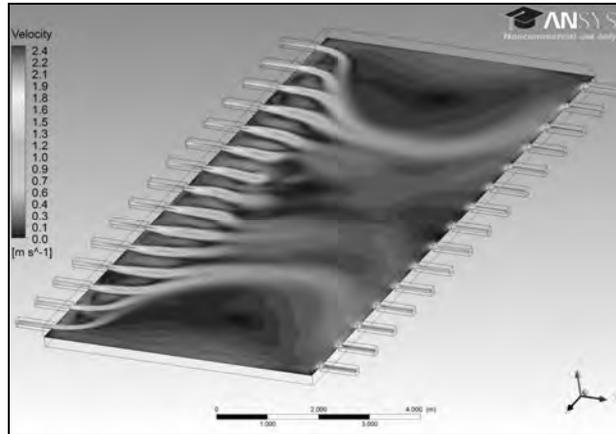


Fig. 8. Air velocity in underfloor cavity - longitudinal section

In Figure 9, the air velocity flows across transverse sections of the holes, axes. An observable increase in air velocity can be seen near the centre of the cavity. This fact is influenced by the course of real pressure acting on the wall at wind speeds of  $3 \text{ m}\cdot\text{s}^{-1}$  (Fig. 7).

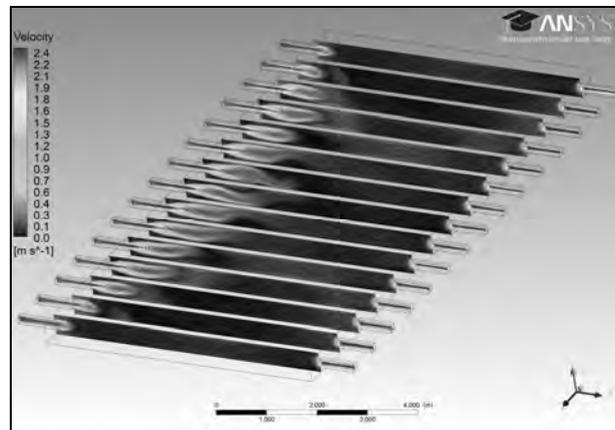


Fig. 9. Air velocity in underfloor cavity - cross section

Figure 10 provides a more accurate estimate of places with limited air velocity. On the right and left side of the cavity around the middle you can observe points of turbulence that slow the rate of air flow rate.

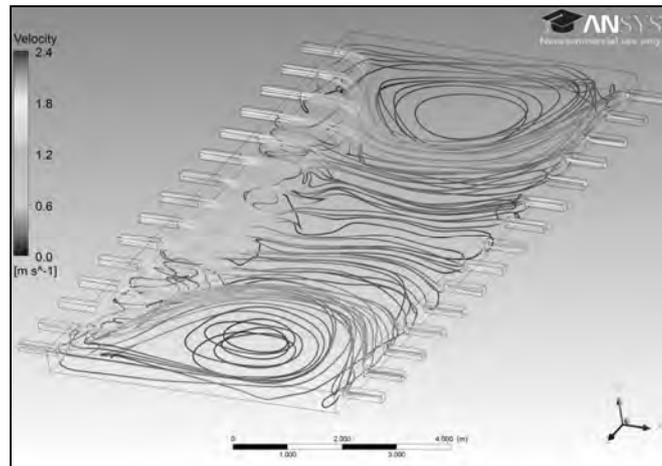


Fig. 10. Streamlines of air velocity in underfloor cavity

From the velocity profiles (Figs. 8-10) it is evident that the air cavity produces a sufficient volume of air flow. For a complete assessment of the air flow, further analysis of air flow rates around the edges of the cavity are required (walls).

Figure 11 depicts a graph of air flow velocity in the vicinity of the shorter sides of the assessed cavity. Assessed sides are divided into 300 equal parts, corresponding to a 20 mm diameter. From the air velocity curve, influenced by the church tower, it is evident that there is a minimum difference between the right and left side of the cavity. Air flow is not zero.

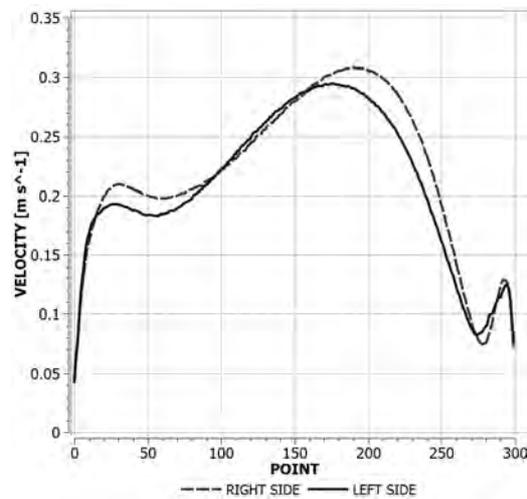


Fig. 11. Air velocity near the shorter sides of the cavity

Figure 12 shows an air flow velocity graph in the vicinity of the longer sides of the assessed air cavity. Assessed sides are divided into 600 equal parts, correspond-

ing to a 20 mm diameter. The chart shows that rates are the same course as pressures from Figure 7. Airflow is not zero.

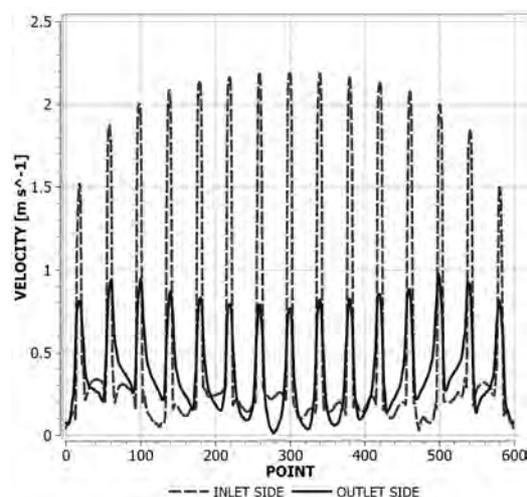


Fig. 12. Air velocity near the longer sides of the cavity

## CONCLUSION

The paper aims to highlight the possibilities of CFD computer simulation programs to assess airflow in underfloor cavities. The application of simple geometric models can accurately confirm or refute the appropriateness of a proposed solution. The above results disclose that the modeled air cavity works reliably. Except for two places that are affected by excessive turbulence (Fig. 10), the velocity of the cavity tends to work reliably.

The given model was realized with an air flow of  $3 \text{ m}\cdot\text{s}^{-1}$ , during the summer with air temperatures approximating  $25^\circ\text{C}$ . It may be considered that the assessment is similar to an evaluation for air flows in a cavity of variable wind speeds and also for winter periods, where average temperatures are below freezing.

This work has directly connection with solved research projects VEGA 1/07/48/11, “Theoretical and experimental analysis of engineering environment systems in relation to their pollution by the effective utilization of renewable resources”.

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## **OCENA PODŁOGOWEGO SYSTEMU WENTYLACJI W BUDYNKACH HISTORYCZNYCH PRZY UŻYCIU PROGRAMU ANSYS**

**Celem artykułu jest zwrócenie uwagi na możliwości zastosowania komputerowych programów symulacyjnych (CFD) do oceny przepływu powietrza we wnękach podłogowych. Przy zastosowaniu prostych modeli geometrycznych można potwierdzić lub odrzucić proponowane rozwiązanie.**

**Słowa kluczowe: podłogowy system wentylacji, budynki historyczne, ANSYS CFX**