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Method of modeling the different solution of ventilated air channels for historical buildings

Ladislav Tazky, Anna Sedlakova

Abstract*—the purpose of the research is to find adequate solution against rising damp in historical buildings. The improvement of this case is with ventilated air channel. Special part of historical buildings are churches because not use routinely as for example museums, galleries. We are designed 4 differently construction of ventilated air channel. There are: open or closed, with overpressure and under pressure. We use for verification relevance these construction we simulated in software Ansys CFX the air flow of channels. We model the equal segment of the channels. The best solution of this construction is the ventilated air channel with under pressure system. In this solution are the highest values of air velocity. Nevertheless this solution is not aesthetic form of construction because the pipes are set on the façade. But these pipes are put in the drainage pipe. This research should be offer for architects the solution against problems of rising damp for historical buildings. For find the right solution is necessary to research everyone case. The aim of the research is to prepare the design process of the ventilated air channels for the architects without simulation every building, cross section or geometry of this construction.

Index Terms—**ventilated air channel, remedial methods, moisture problems, historical buildings.**

I. INTRODUCTION

Moisture is a major source of damage in historic solid masonry. Rising damp is a well-known phenomenon around the world and occurs when groundwater flows into the base of a construction and is allowed to rise through the pore structure. From practical experience it is known that many factors may play a role regarding permeability problems in masonry. The amount of possible causes of moisture problems in historic masonry underlines the complexity of this phenomenon. Evaporation is an important factor in rising damp. The surface of an affected wall contains moisture that has risen from the ground and this moisture is then subject to evaporation. The factors controlling evaporation include: temperature, humidity, air movement and surface. One of the special categories of historical building are churches. The reconstruction of these buildings is difficult and extraordinary. Historical buildings are sensitive to moisture, temperatures, especially churches. Villagers repaired the small errors on the walls, but they didn´t use the correct methods and materials, nowadays they use cement and other adhesive mortar based on the cement. This materials must not be used in historical buildings with moisture problems because we worsen the state instead repairing it. Therefore we can use many construction materials to repair or relieve problems with moisture. The best and the most popular in the past is the ventilated air channel around the perimeter of the wall. Many types of these systems exists, for example: overpressure or under pressure channels, open or closed systems [1, 2, 6, 7].

Fig 1. – The church Gemersky Jablonec in year 1932 (Author: Ladislav Tazky)

II. HISTORY OF THE CHURCH

The church in Gemersky Jablonec is the oldest in the micro region Medves (Figure 1 and 2), which is a valuable monument of the Romanesque architecture. In the construction of the church architect used different materials. The foundation is made of bricks and above stone blocks are used. The walls were probably plastered. In the 18th century the church was modified. The original Romanesque windows on the south side of the church were walled up and new and larger ones were created instead. The new windows are a feature Baroque architecture. In the 18th century the sacristy was added to the north side. In 1933 the church was renovated. In 1969 an archeological survey was conducted where archeologists discovered the remains of the fortification walls protecting the building. In 2008 the dehumidification of the walls begun from the outside and during this process another archeological research was conducted which confirmed the origin of the Roman church.

Fig 2. – The church Gemersky Jablonec nowadays (Author: Ladislav Tazky)

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III. DESCRIPTION OF DAMAGES

During the visual survey it was found that the moisture content of the internal masonry pillars reaches up to the height at around 1700-1900 mm. The situation was the worst at the apse of the east side of the church. On the inner surface of the plaster there was visible efflorescence and mildew occurrences especially in the higher parts of the plinth. On the outside of the walls there are still visible lichens, mosses and algae. During the reconstruction of the 80es a gutter walkway was built around the church which only worsened the situation. The biggest problem is the concrete sidewalk on the west side of the church, which compresses the water towards the walls and concentrate at the foundations (Figure 3, 4, 5).

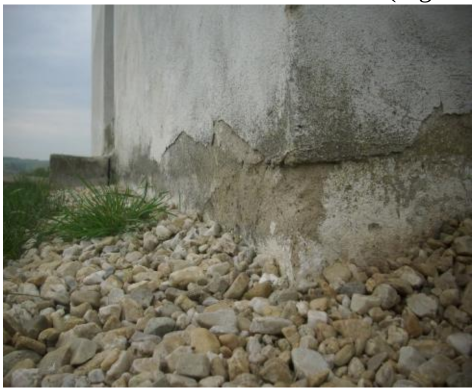

Fig 3. – Damages on external surface (Author: Ladislav Tazky)

Samples were taken from the perimeter walls for moisture laboratory evaluation. Each samples is taken from the plaster or mortar from the peripheral wall. These samples were collected from the bottom of the wall. The highest values of moisture at around 9% have been measured on the east side of the outer walls of the apse. These samples were collected from the bottom of the wall. In the summer of 2013, work began on the dehumidification of masonry which started by removing of the original plaster to the height at around 1500 mm and replaced by the appropriate remediation plaster.

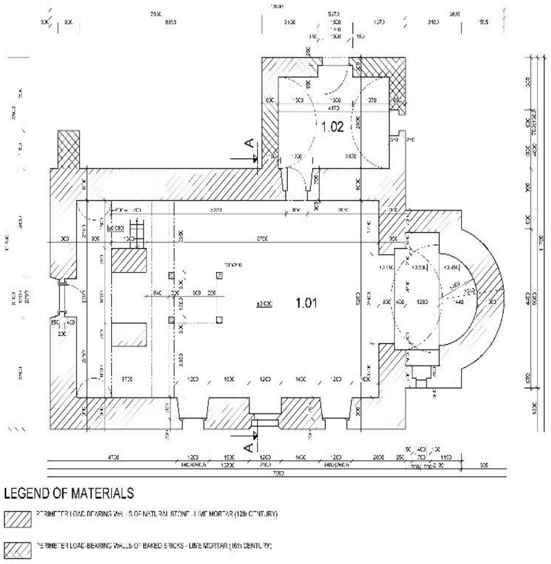

Fig 4. – Floor plan of the church in Gemersky Jablonec (Author: Ladislav Tazky)

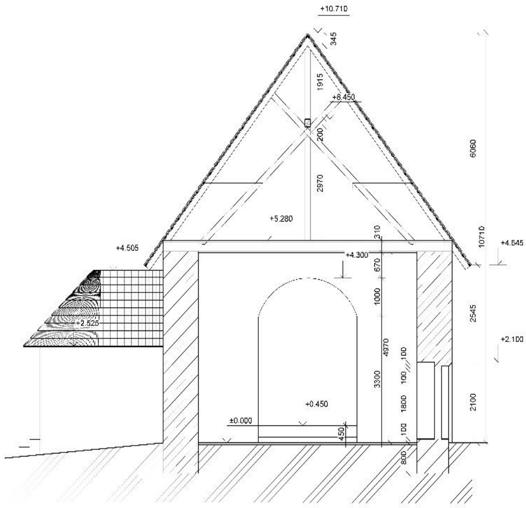

Fig 5. – Section A-A of the church in Gemersky Jablonec (Author: Ladislav Tazky)

Predicted sources of moisture:

- The increased surrounding terrain, which increase the concentration of the moisture on the outer walls;
- The waterproof PVC covering which was laid in the 80es on the original ceramic tiles;
- The waterproof plinth which is formed of the synthetic color on the walls (Figure 6);
- No roof drainage system. Rain is driven by the wind on the perimeter walls and the water runs down the surface;
- The moisture regime of the church is inappropriate, the worst of all is the unsystematic and almost no ventilation;
- The removed concrete gutter pavement in 2008 which was replaced with a drainage pipe in the gravel embankment, which was only effective for 2 years and thus does not fulfill its function.

Fig 6. – Damages on internal surface of the church (Author: Ladislav Tazky)

IV. REMEDIAL METHODS

Since the church is a protected cultural monument and a historic value should be particularly sensitive to any remediation done. To improve the technical condition of the church minor structural modification are required.

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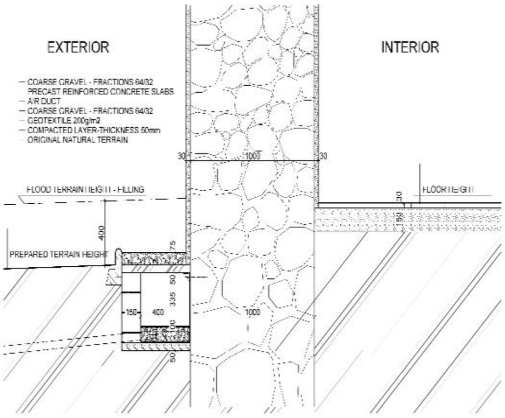

Fig 7. – Detail of the foundation with air channel (Author: Ladislav Tazky)

These are:

- Resolve roof drainage around the building;
- Resolve the drainage of the ground around the church especially on the south side where the slope of the terrain directs the water towards the church;
- Landscaping around the church – the removal of the embankment;
- Remove PVC floor and leave the orogonal ceramic tiles uncovered;
- Remove the synthetic color from the inside walls;
- Use of ventilated air channel (Figure 7).

V. THE DESIGN OF VENTILATED AIR CHANNEL

A. Geometry of air channel

The drain pipes will be replaced with outdoor air channels. The channel must be masoned of the ceramic burned bricks with lime-cement mortar to ensure the natural evaporation of moisture from the soil through the brick masonry. The bottom of the air channel will be filled with gravel; the drain pipe will be placed in this layer to ensure the drainage of water. The next step will be the coverage of the channel with precast concrete panels. These panels are perforated to ensure the natural evaporation from the channel (Figure 8 and 9).

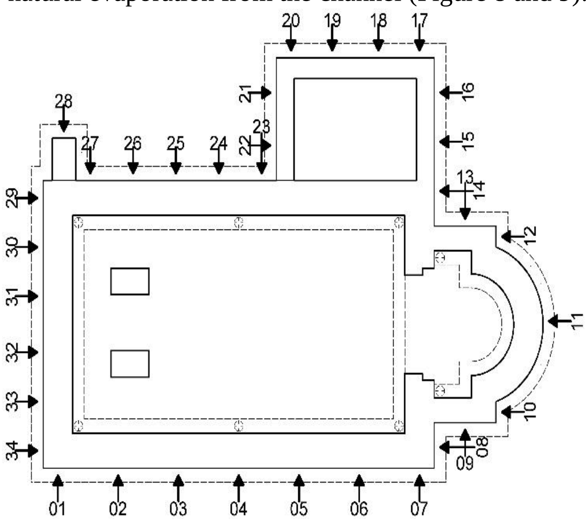

Fig 8. – Inlets for the ventilated air channel (Author: Ladislav Tazky)

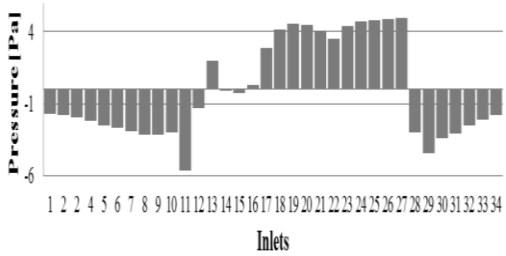

Fig 9. – Air pressure in inlets (Author: Ladislav Tazky)

B. Simulated variants of the air channel

We designed the cross-sections dimensions of ventilated air channel in 10 variants. The size and values of air pressures and air velocities are shown in the Table 1. The air pressure and air velocity values are from the second simulation. In the second simulation we used the values of air pressure what we obtained from the first simulation. We designed the church and terrain in the first simulation to get the properties of the wind on the surface church [9].

Table 1. – Air velocity and air pressure in the air channel for each variant (Author: Ladislav Tazky)

Simulated Variants	Dimensions [mm]	Air Velocity [m/s]	Air Pressure [Pa]
Variant 1	400 x 400	0.15552	0.01719
Variant 2	400 x 450	0.15990	0.01470
Variant 3	400 x 500	0.14958	0.01343
Variant 4	400 x 550	0.13990	0.01239
Variant 5	400 x 600	0.13008	0.01153
Variant 6	**500 x 400**	**0.16319**	**0.01351**
Variant 7	500 x 450	0.14922	0.01215
Variant 8	500 x 500	0.13762	0.01103
Variant 9	500 x 550	0.12830	0.01020
Variant 10	500 x 600	0.12141	0.00945

C. Numerical model of the air channel

The first model was realized with an air flow of 3 m/s, during the summer with air temperature approximating 25°C. In the second model we used obtained values of pressure in monitored points, what represented the location of the inlets on the wall in the first model (Figure 10, 11, 12) [10].

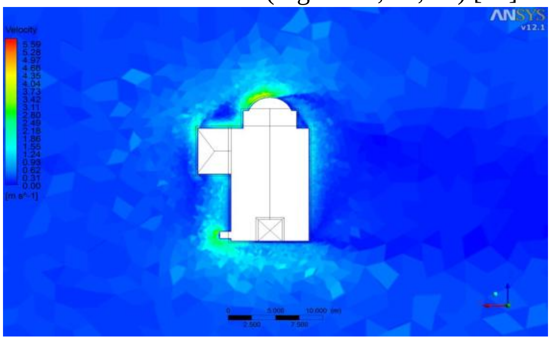

Fig 10. – Coloured velocities around the church on height 15 cm (Author: Ladislav Tazky)

D. Results of numerical simulation

In the Figure 11 is displayed dependence of the air velocity on the depth of the air channel. If the depth of the air channel is higher air velocities are lower. Therefore in the final numerical simulation we used lower depth of the air channel

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with the enlarged width. Final cross-section dimensions of the air channel are 500 x 400 mm (Variant 6).

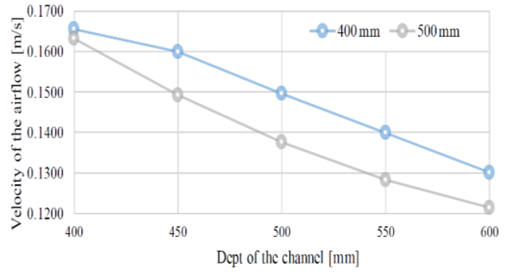

Fig 11. – Dependence of the velocity and depth of air channel (Author: Ladislav Tazky)

The Figure 13, 14, 15, 16 displayed streamlines air in the air channel around the church. The streamlines air is colored according the air velocity. In this part of the church is the worst situation, because water content in the masonry is around 9%. The tested samples have been collected from the bottom part of the masonry wall. Results obtained from the numerical simulation in the software ANSYS CFX are satisfactory in the complicated parts of the church as well as at the apse [11].

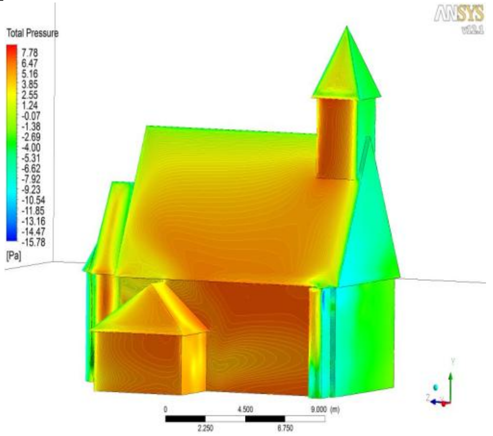

Fig 12. – Model of the building and pressures on the surface of the church (Author: Ladislav Tazky)

The graph in Figure 17 displayed air velocity in the monitored points 1 – 118 in the second model. Location of the monitored points is in the center of the channels in the distance 300 mm.

Fig 13. – Streamlines coloured by air velocities in the Variant 6 around the church (Author: Ladislav Tazky)

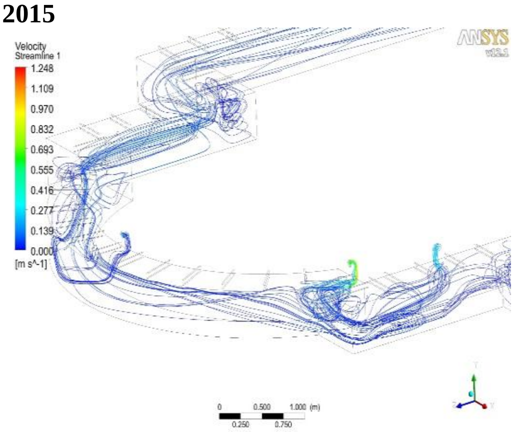

Fig 14. – Streamlines colored by air velocities in the Variant 6 around the apse (Author: Ladislav Tazky)

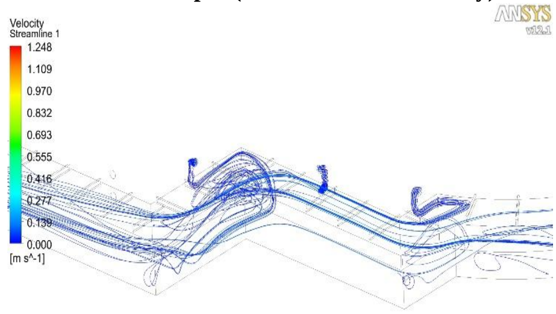

Fig 15. – Streamlines colored by air velocities in the Variant 6 in complicated detail (Author: Ladislav Tazky)

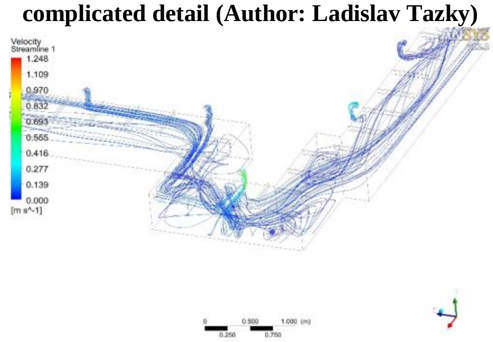

Fig 16. – Streamlines colored by air velocities in the Variant 6 around the column (Author: Ladislav Tazky)

The air channel around the church Gemersky Jablonec is simulated in many different variants, see Table 1. Results obtained from the numerical simulation in the software ANSYS CFX showed cross-section 500 x 400 mm (Variant 6) as the best for this church. In this case is air velocity in the air channel highest as well as maximal drying effect of the masonry. Final results showed average air velocity in the air channel on the value 0.032 m/s, more.

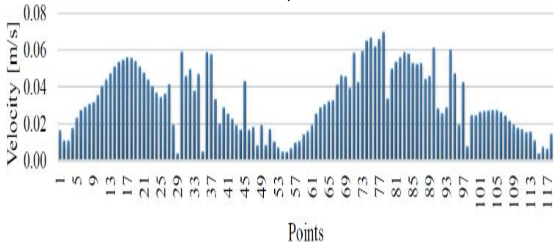

Fig 17. – Air velocities in the air channel with the dimension 500 x 400 mm (Variant 6) (Author: Ladislav Tazky)

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VI. OTHER TYPES OF THE SYSTEMS

A. Open system of the ventilated air channels

One of the most popular system is the open system without inlet and outlet pipes. The construction of the channel consist of the wall and base of the channel, and the top of it is vacant or with iron bars. This system is the best for churches but not esthetic because around the building there is an empty hole (Figure 18).

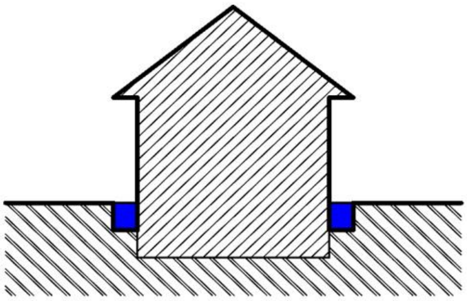

Fig 18. – Open system of ventilated air channel (Author: Ladislav Tazky)

B. Closed system of the ventilated air channels with overpressure

The second type is the closed channel with overpressure air ventilation. The outdoor dry air enters the channel through the inlet pipes and the damp air is evaporated through the outlet openings. The advantage of this type is that the channel is hidden; only the inlets and outlets are visible on the façade or on the ground. The prefabricated cover plates are covered with gravel (Figure 19).

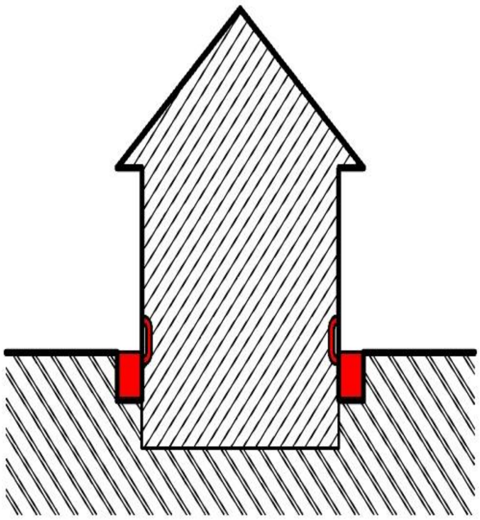

Fig 19. – Closed system of ventilated air channel with overpressure (Author: Ladislav Tazky)

C. Closed system of the ventilated air channels with under pressure

The third type is the closed system with under pressure air ventilation. The under pressure in the channel is ensured with ventilation heads above the roof. The inlet openings are on the top of the channel or in the wall. The outlets are situated on the façade, this is a tall pipe, and we can hide it in roof drain or on the façade only (Figure 20).

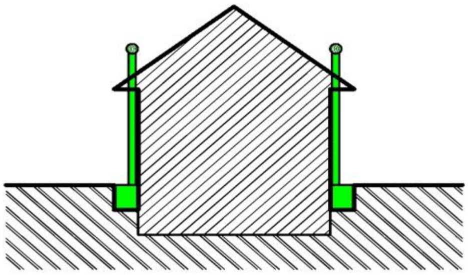

Fig 20. – Closed system of ventilated air channel with under pressure (Author: Ladislav Tazky)

D. System of ventilated plinth

The last one is the ventilated plinth. This type is the soft method of the ventilation, because between the plinth and the wall is a thin layer of air. The inlets are situated at the bottom of the plinth and the outlets on the top of the plinth (Figure 21) [5].

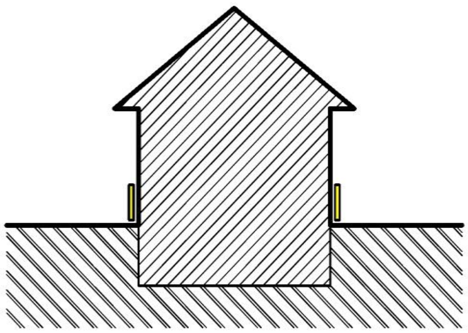

Fig 21. – Ventilated plinth system (Author: Ladislav Tazky)

VII. MODEL OF THE VERSIONS FOR NUMERICAL CALCULATION

E. Geometry of the domains

These numerical applications present the aerodynamic analysis of the building sections and all versions of ventilated air channels. We designed the 5 m wide section in the software ANSYS CFX surrounded with air boundary. From the 2D model of the section we transformed a 3D version with the function “extrude”. The sizes of the environments are designed according the principles of the air flow. The present simulation is considered the turbulence fluctuation in the inflow boundary conditions. The Figure 5 shows the geometry of the air environment.

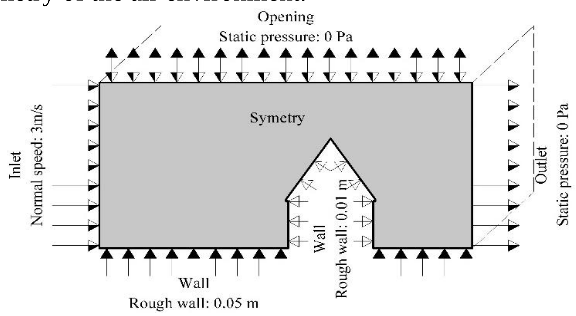

Fig 22. – Geometrical characteristics of the computational domain for a section model (Author: Ladislav Tazky)

The general domain size for the numerical model was set at 113.2 x 5.0 x 35.0 m^3. The distance between the inlet section

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and the center of the building was 74.1 m. The full height of the building is 10.96 m, respectively the height of the wall was 4.7 m; the width was 8.2 m and the roof angle was 54.64° (Figure 22) [3, 4].

F. Geometry of the versions

The open system air channels are the simplest solution. The channel is situated at the perimeter of the building, near the base. The width of the channel was 0.4 m and the height was 0.65 m. The channel isn´t closed with iron mesh or with other cover, the air is flow free in the channel (Figure 23 – left).

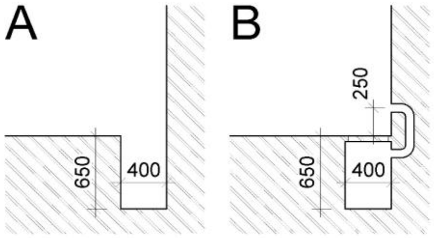

Fig 23. – Dimensions of versions: A – open channel, B – closed channel with overpressure (Author: Ladislav Tazky)

The geometry of closed system with overpressure air ventilation is similar. The width of the channel was 0.4 m and the height was 0.6 m, and the cover plate was 0.05 m. The air channel is connected to the exterior air with pipes (inlets) with a diameter of 0.075 m. The heights of the inlets is 0.25 m on terrain. The outlets are situated on the terrain, the length of the outlets was 0.35 m and the width was 0.025 m (Figure 23 – right). The next version is similar, and the dimensions are the same. The inlet pipes are replaced with pipes at the full height of the wall. The end of the pipes are above the roof with 0.5 m. The outlets in this case function as inlets, and the pipe above the roof as the outlet. The diameter of the pipe is 0.075 m (Figure 24 – left). The last system is the ventilated plinth. In this case we used the basic dimensions for the simulation. The height of the prefabricated plates is 0.5 m and the thickness is 0.025 m. The air channel under the plates is 0.6 x 0.05 m. On the base there are the inlets with a height of 0.05 m and on the top of the plates are outlets with a height of 0.05 m(Figure 24 – right)[5].

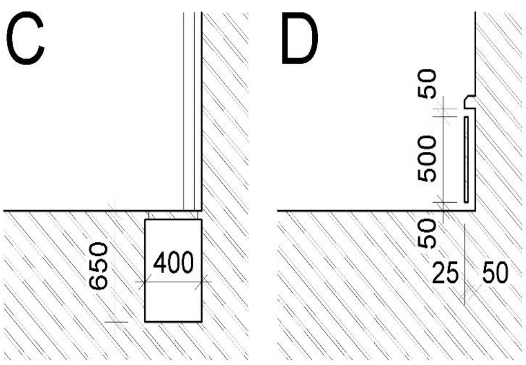

Fig 24. – Dimensions of versions: C – closed channel with under pressure, D – ventilated plinth (Author: Ladislav Tazky)

G. Mesh of the models

The overall model is meshing to the maximum size of the elements of 0.3 m. Surfaces or edges are condensed to the element size of 0.25 – 0.05 m, depending on the versions. Figure 25 and Figure 26 shows the mesh of the model, especially the ventilated plinth. This model is constituted by 6,495,987 elements and 1,146,303 nodes. Time period of generating is 5 – 7 min.

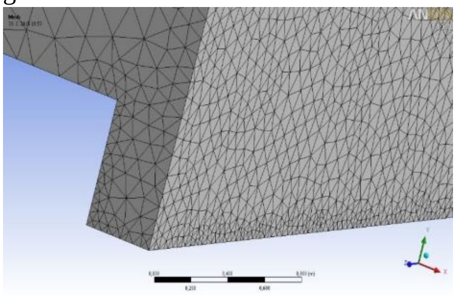

Fig 25. – Detail view of mesh generation in open air channel (Author: Ladislav Tazky)

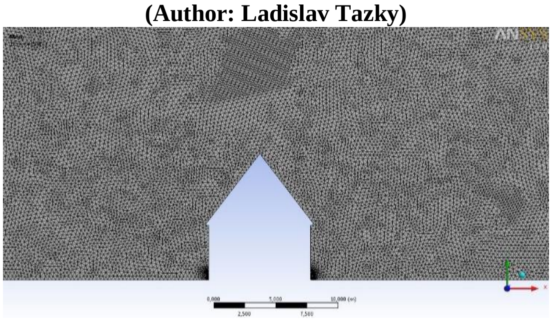

Fig 26. – Mesh characteristics of the computational domain for section model (Author: Ladislav Tazky)

H. Boundary conditions

In this case we used a SST (Shear Streas Transport) numerical model. Temperature of the overall model is 25°C (summer temperature). Apparent density of the air is 1.1845 kg/m^3 and the dynamic viscosity of the air is $1.86159.10^{-5}$ kg/m.s. All section models of the channels are simulated by a wind flow of 3 m/s. In Table 2 we show the boundary condition parameters for the model [3, 4].

Table 2. – Parameters of the setup model (Author: Ladislav Tazky)

Name of surface	Boundary type	Parameters
Inlet	Inlet	Normal speed 3 m/s
Outlet	Outlet	Relative pressure 0 Pa
Sky	Opening	Relative pressure 0 Pa
Sides	Symetri	-
Terrain	Wall	Roug wall = 0,05 m
Building	Wall	Roug wall = 0,01 m

VIII. RESULTS OF THE SIMULATION

The Figure 27 displayed contour of air in the open air. Channel around the church. The streamlines air is colored according to air velocity. The tested samples have been collected from the bottom part of the masonry wall. Results obtained from the numerical simulation in the software ANSYS CFX are satisfactory in the complicated parts of the church as well as at the apse.

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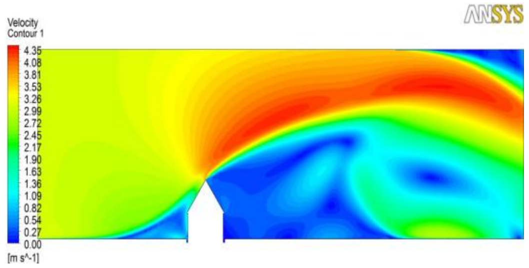

Fig 27. – Air velocity contour of open air channel model (Author: Ladislav Tazky)

In the Figure 28 is displayed air velocity contour in the channel. Therefore in the final numerical simulation we used lower depth of the channel with the enlarged width. Final cross-section dimensions of the air channel are 650 x 400 mm [8].

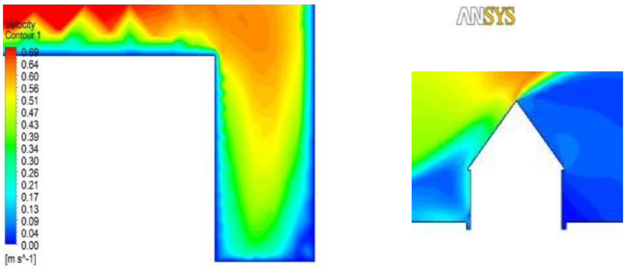

Fig 28. – The air contour of the open channel (Author: Ladislav Tazky)

IX. CONCLUSION

Many construction solutions of air channels exist for historical buildings with damp problems in walls. The designed versions are the most widely used solutions as the: open air channel, closed air channel with overpressure, closed air channel with under pressure, ventilated plinth. We simulated these 4 different versions, because these solutions are practiced in the reconstruction of historical building. The versions are designed and set in accordance with regulations. Many literatures write about designing the right dimensions of air channels for example: Balík M. in the book "Dehumidification of buildings" As results of the simulations we will compare and find the best solution. Obviously, not all versions or models are right for all environments. Modeling is necessary in every case and verification of its function. In the future we want simulate the next versions and make a real model of the ventilated channel and sections of channel. The obtained data of the real simulation on the model we compare with the simulation in program Ansysy CFX and prepare the best solution for historical buildings with moisture problem.

X. ACKNOWLEDGMENT

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REFERENCES

[1] M. Vlcek and P. Benes, "Disturbances and reconstruction of building – Modul 1," pp. 45-51, July 2006.

[2] D. Young, "Salt attack and rising damp," A guide to salt damp in historic and old building,, pp. 35-40, Jan. 2008.

[3] T. Brestovic, N. Jasminska and M. Kubik "Development of software support for ANSYS CFX,"pp. 9-10, May 2013.

[4] L.B. Alexander and M.A. Armando, "Aerodynamic analysis of buildings using numerical tools from computational wind engineering," pp. 23-28, September 2010.

[5] M. Balik and J. Solar, "100 traditional details of buildings – rising damp,, pp. 45-47, Jan. 2011.

[6] E. Horanska, and V. Dvorakova "National cultural heritage, importance and reconstruction a financial support,"pp. 5-45, February 2011.

[7] M. balik, et.al., "Dehumidification of buildings Vol. 2,, pp. 45-47, Jan. 2008.

[8] T. Rencko, A. Sedlakova, "Assessment of under floor ventilation of historic buildings using Ansys CFX,"pp. 1-6, March 2009.

[9] M. Havel, "Procedure for remediation of damp masonry locks on the upper Vimperk,"pp. 1-6, October 2008.

[10] J. Rehak, "Survey of drainage tunnels ib the monastery Milevsko,"pp. 1-6, October 1993.

[11] M. Balik, "Drying of the masonry,"pp. 1-6, October 2009.

AUTHOR'S PROFILE

Ladislav Tazky-internal doktorand on Civil Engineering Faculty at Technical University of Košice, Publication: Numerical simulation of air channel in church Gemersky Jablonec in: enviBuild 2014, Possible solutions for ground slabs of energy efficient buildings in: enviBuild 2014, The possibilities for remediation of damp masonry – church of St. Abdon and Sennen in Gemersky Jablonec in: PhD. Student conference – Young scientist 2014, Remedial method against moisture problems – Church of St Abdon and Sennen in Gemersky Jablonec in: SSP – Journal of Civil Engineering, Solution of the rising damp in the church in Gemersky Jablonec in: Conference SGEM 2014.

Anna Sedlakova- head of the department of building physics on Civil Engineering Faculty at Technical University of Košice, Publications: Analysis of environmental aspects in high energy performance family house – case study in: Chemical engineering transaction, Evaluation of structures design concept of lower structure from embodied energy and emissions in: Chemical engineering transaction, Alternative wall insulation for energy efficient building in: Conference SGEM 2014, Effect of ventilation on indoor environmental quality in buildings in: Environmental Engineering 2014..