Underground ventilated wall based on TRC blocks

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Abstract. Ventilated wall is an air-insulating method, which principle is to create a ventilated cavity along the surface of remediated underground wall (usually masonry). The paper describes an innovative solution of this remediation method based on the precast blocks made from textile-reinforced concrete - TRC. The main advantages of the solution (compared to traditional constructions - masonry, hollow bricks filled by cement mortar, monolithic concrete) are low labour difficulty, fast montage and high durability. Since the blocks are not structurally connected or anchored to remediated structure, it is a non-invasive method, which is also suitable for installation in historically valuable buildings. The technical solution is protected by patent CZ307501(B6).

1. Introduction
By combining high-strength concrete and textile-reinforcement (TRC), there is possibility of extensive use of precast elements in the field of refurbishment of underground parts of buildings (in terms of protection against moisture). The biggest potential for the use of precast elements is in the field of air-insulating methods. These methods are often used remediation technology designed for reduction of moisture content in masonry - this applies to older buildings that lack functional waterproofing envelope of the substructure [1]. This group of remedial measures is designed to maximize the evaporation of water (in the form of diffusing water vapour) from the building structure or, alternatively, from the surface of the adjacent terrain. The result is a reduction of moisture content in building structures and preventing transport of liquid water into a higher part of masonry.

For effective evaporation of water from the structure, it is necessary to ensure an intense exchange of air in immediate vicinity of surface so as not to achieve 100% relative humidity of the adjacent air layer. Therefore, all air-insulating remediation systems are designed in a way that allows efficient airflow in the cavity created by the measure. At the same time, it is important that the supply air has the low relative humidity $\phi$ [%]. Therefore, air must be brought into the ventilated cavity from the outside. However, this may be a problem if the ventilated cavity is located at the interior surface of the structure. In winter, the temperature inside the ventilated cavity can causes undesired condensation on the surface of structure. Each design of the ventilated cavity must therefore be evaluated in terms of risk of condensation. From this point of view, it is a much simpler solution to place the ventilated cavity in the exterior so that the cavity is separated from the interior by the thermal insulating envelope of the building. For the right work of air insulating remediation measure, the surface of the remediated structure should be modified as diffusely open - allowing the movement of water vapor. At the same time, it should have as large a surface as possible. For this reason, it is advantageous to remove the
original plaster from the masonry and to scrape the joints between the bricks to maximize the surface for evaporation.

Current air-insulating systems include: ventilated walls (can be made from the exterior or interior and above or below ground level), ventilated floors, ventilation ducts in the masonry (which are usually less efficient), ventilated plinths and ventilated horizontal tunnels. Some of these air-insulating systems have already been modified by the author using specially shaped reinforced concrete blocks [2,3].

The advantage of air-insulating systems is that they can completely replace the costly additional waterproofing envelope of substructure [4] (in the cases where the moisture level in masonry is not too high). An important advantage is also that it is a non-invasive method which is suitable for use in historically valuable buildings.

2. State of the art, motivation

Ventilated wall is an air-insulating method, which principle is to create areal ventilated cavity along the surface of remediated underground wall (usually masonry). The ventilated wall differs from the ventilated horizontal tunnel by being installed all over the basement wall, while the tunnel is only a linear element with a small high of remediated area of structure. The ventilated tunnel is typically installed along the foundations at the non-basement buildings, not at the basement walls [3]. The ventilated wall can be located either on the interior or exterior side of the remediated perimeter wall. The interior ventilated wall can be realized from standard types of vertical non-load-bearing structures - such as gypsum boards on grids or masonry. The exterior ventilated walls placed in the contact with ground environment must be sufficiently rigid due to the pressure of the adjacent soil. At the same time, the exterior wall must be made from durable materials as they are exposed to the water contained in the surrounding soil environment. An important advantage of the external ventilated wall over the inner wall is the interruption of horizontal capillary transport of water from the soil environment to the basement wall. As a result, the effect of the exterior construction is significantly higher because there is a significant reduction of the moisture content in building perimeter wall that has the associated positive impact on its building-physical properties, such as increasing the compressive strength, reducing the thermal conductivity, reducing the biocorrosion and slowing the deterioration of the binder components. Another advantage of using the exterior wall over the inner wall is that there is no reduction of floor space in the basement.

External ventilated walls are mostly realised from masonry - usually from hollow bricks filled by cement mortar or form sand-lime bricks, exceptionally from the monolithic reinforced concrete (which is difficult and costly). In the case of a ventilated wall from bricks, the durability of this structure is limited due to direct contact with water and moisture in the soil environment. Another disadvantage of the masonry structure is the high risk of deformation due to the long-term effect of the ground pressure. Deformation occurs because the wall is not burdened with any other vertical load that would have a positive impact on the direction of the internal forces resultant (necessary for ensure the sufficient masonry stability even over a long period of time). In terms of mechanical parameters and stability, it is a much better solution a ventilated wall made from monolithic reinforced concrete but it is the most expensive variant - the necessity of extensive excavation work, complicated formwork in a confined space, technological pauses, solution of working gaps. A suitable alternative to the above-described contemporary design of exterior ventilated walls is a structure described in this paper.

3. Underground ventilated wall based on TRC blocks

The disadvantages of existing external underground ventilated walls based on bricks (low durability, risk of deformation, high labour difficulty) even on the basis of monolithic reinforced concrete (high price, difficult to implement) are removed by using of precast reinforced concrete wall from high-strength textile-reinforced concrete - TRC. This solution consists of a TRC blocks (Figure 1-2) which are placed side by side along remediated basement wall and thus create an air cavity allowing the evaporation of water from the masonry. Thanks to the use of TRC which includes a high-strength concrete technology, a small thickness of the block is possible. Using high-strength concrete also ensures
high durability of the element in permanent contact with the wet soil environment, since high-strength concrete has a closed microstructure that prevents the transport of liquid water inside the structure. Thanks to this, it is not necessary to design any additional protection against ground water - no additional waterproofing envelope is necessary, as in the case of brick walls.

![Figure 1. Special shaped underground block from TRC: 1 – whole block, 13 – basic plate, 14 – upper support element, 15 – lower support element, 16 - handle for manipulation, 17 - extended upper rib, 18 – lower rib, 19 – mid rib, 20 - transverse reinforcing rib, 21 - drain hole, 22,23 - tongue-and-groove system.](image)

The block from TRC has a cross-sectional shape of the approximate letter "E" in its final position, the predominant dimension is height - the blocks are laid vertically. The block is made up of a basic plate, from which the perpendicular U-shaped support elements are drawn in the upper and lower parts. In the mid part of the block, there is another support element which stability is ensured by transverse reinforcing rib. The elements placed side by side creates continuous air cavity along the remediated wall.

In the middle of the lower U-shaped support element a small hole is placed. This hole serves as a drain for water that could eventually flow into the air cavity. The blocks are equipped with a tongue-and-groove system, which serves to ensure the uniform subsidence of the individual blocks. Both the tongue and the groove have a trapezoidal shape, the groove being slightly larger than the tongue so that the adjacent blocks can snugly snap into each other. The dimensions of the block do not allow manual handling due to too much weight - therefore the element is equipped by handle for manipulation in its upper part. The large dimensions of the block are due to the requirement for maximum mounting speed and the simplicity of solution.
The basic system from the blocks is complemented by a specially shaped cover sheet that overlaps the upper part of the fitting and serves as a protection against the penetration of the leaking water into the cavity (Figure 3). The cover metal sheet is located close to the surface of the terrain and is shaped in an inclined gradient so that the leaking water flows into the adjacent landfill. In its upper part, the metal sheet is formed into a vertical position and is attached to the peripheral wall of the remediated object. In the case of specific aesthetic requirements, the required surface of the plinth can be glued to the sheet (ceramic tile, stone tile etc.). In the case of historically valuable buildings (protected monuments), there is the possibility to terminate the cover metal sheet under the surface (it is necessary to ensure its waterproof connection to the surface of the wall).

**Figure 2.** 3D model of concrete block: left - single block, middle - block assembly (external view), right - block assembly (internal view).

**Figure 3.** Example of block installation at the building: 1 – concrete block, 2 – remediated masonry, 3 – ventilated cavity, 4 – permeable gravel, 5 – drainage, 6 – landfill, 7 – cover sheet, 8 – terrain surface, 9 – plinth (part of the cover sheet), 11 – cover pavement, 12 – ground.
For correct function of the entire system, the air cavity formed by blocks must be ventilated. Cavity ventilation must be ensured by installing suction and vent holes - it can be provided by a ducts located in a vertical grooves in the masonry (Figure 4). The opening of the holes inside the cavity must be situated at different heights. To provide adequate ventilation efficiency, there is strongly recommended to equip the openings with axial fan of low power. In winter, it is recommended to cover the ventilation holes (to prevent access of the cold air from the outside) to avoid condensation of water vapour inside the cavity. To increase the efficiency of the remedial measure it is also recommended to scratch the joints of remediated masonry to a depth of 20 to 30 mm (this will increase the area of the evaporation).

![Figure 4. 3D model of block installation at the building with marked vent holes equipped with a fan (cover sheet is not displayed, for clarity).](image)

Blocks are assembled into the excavation which bottom is performed from compacted gravel. The gravel layer must be made as a drainage layer to prevent leakage of subsurface water into the space of the cavity created by blocks. From this point of view, it is highly recommended to install drainage pipes into the compacted gravel layer. After laying the block to the desired position, the block must be fixed on its place by using of temporary strut before the excavation is filled by soil (the strut is removed when the excavation is filling). Once finished, the block is fixed in its position by ground pressure - therefore no anchoring is needed. The absence of anchoring is advantageous in terms of acceleration of assembly and at the same time in the case of historically valuable buildings there is no breach of the original historical structure.

4. Discussion
The main advantages of the technical solution described above (compared to traditional constructions: masonry, hollow bricks filled by cement mortar, monolithic concrete) are low labor difficulty (fast montage) and high durability. Low labour difficulty is due to a simple installation of the system to the building, without the need for any wet processes. High durability is due to the waterproofing of used material (HPC) and the low risk of deformation from the adjacent soil (compared to the masonry variant). Since the blocks are not structurally connected or anchored to a rehabilitated structure, it is a non-invasive method, which is also suitable for installation in historically valuable buildings (this is also due to the resulting “invisibility” of the measure, which is common to all construction variants). The
only one disadvantage is the necessity of using the lifting device for installation of the blocks into the excavation.

The technical solution is protected by patent CZ307501(B6), granted in 2018 [5].

5. Conclusion
The special shaped block from TRC designed for underground ventilated wall demonstrated that using of TRC precast elements opens up new ways of solution for traditional construction details in buildings. The advantages of this approach are evident: easier and faster assembly, higher durability and new additional functions. In the future, a further specialized precast systems based on TRC elements which will replace some traditional structures in buildings can be expected.

Currently, preparation for the production of the first prototype of the TRC underground wall block is performed. The abovementioned patent CZ307501(B6) which contain the technical solution presented in the paper, is valid only for Czech Republic, in other countries is free to use.

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References
[1] Franzoni E 2018 Journal of Cultural Heritage. 31 S3
[2] Pazderka J and Hájek P 2017 9th International Conference on Fibre Reinforced Concretes (FRC), Textile Reinforced Concretes (TRC) and Ultra-High Performance Concretes (UHPC) (Bristol: IOP Publishing) p 246
[3] Pazderka J, Hájková E and Jiránek M 2017 Acta Polytechnica. 57(5) 331
[4] Pazderka J and Zigler R 2013 CESB 2013 - Central Europe Towards Sustainable Building 2013 (Prague: Grada Publishing) p 163
[5] Pazderka J and Reiterman P 2018 Patent CZ307501(B6) (Prague: Industrial Property Office)