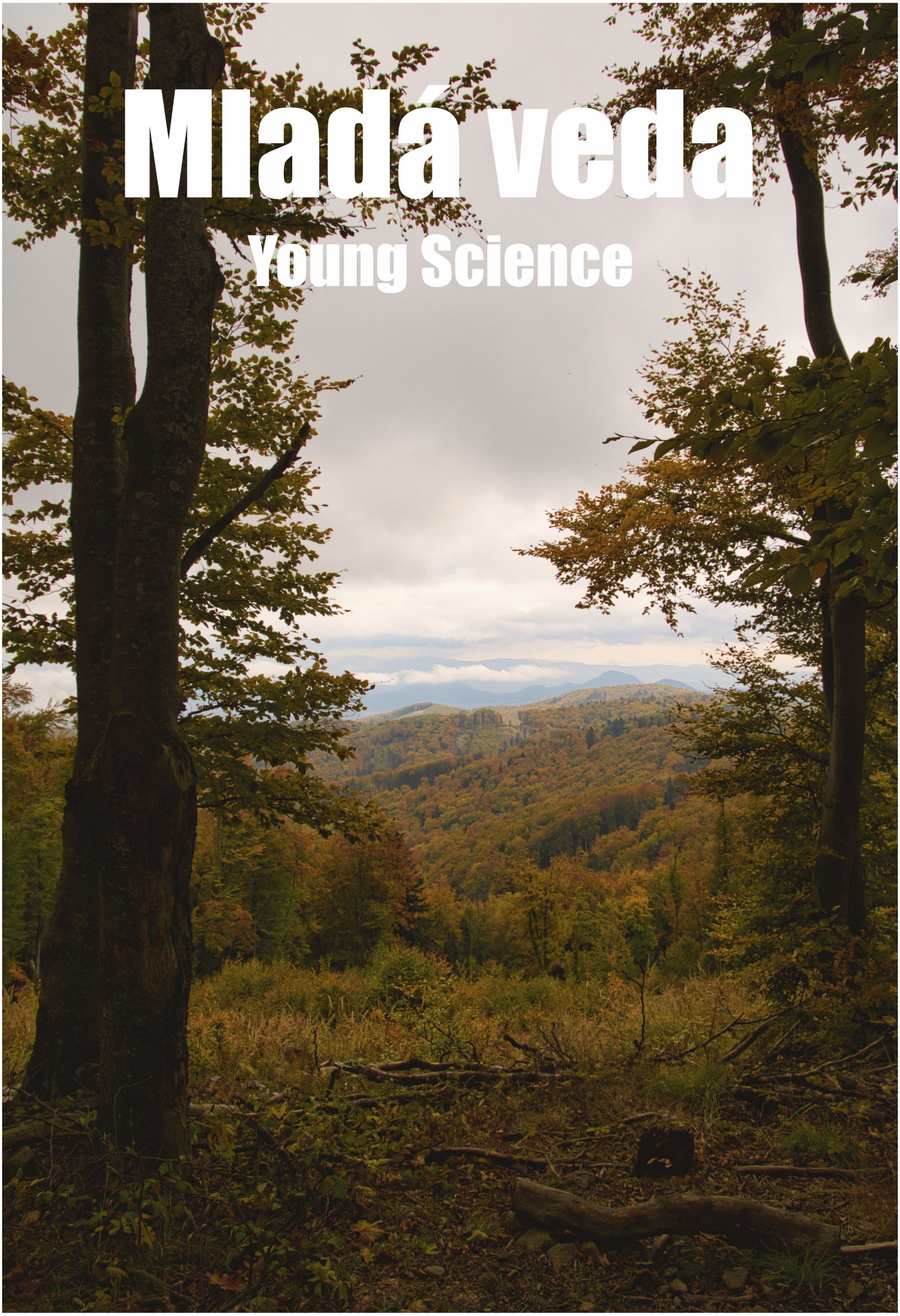
ISSN 1339-3189
5/2026

Mladá veda
Young Science



www.mladaveda.sk

Mladá veda
Young Science

MEDZINÁRODNÝ VEDECKÝ ČASOPIS MLADÁ VEDA / YOUNG SCIENCE
Číslo 5, ročník 14., vydané v septembri 2026
ISSN 1339-3189, EV 167/23/EPP
Kontakt: info@mladaveda.sk, tel.: +421 908 546 716, www.mladaveda.sk
Fotografia na obálke: Pohorie Čergov. © Branislav A. Švorc, foto.branisko.at

VYDAVATEĽ
Inštitút pre vedu, kultúru a spoločenský rozvoj
IČO: 57728038, Bajkalská 12B, 080 01 Prešov, Slovensko
v spolupráci s vydavateľstvom UNIVERSUM-EU, spol. s r. o.

Mladá veda
Young Science
ISSN 1339-3189

Vol. 14 (5), pp. 194-201

INVASIVE REMEDIATION TECHNOLOGIES FOR MASONRY DEHUMIDIFICATION AND MODERN APPROACHES TO MOISTURE DIAGNOSTICS

INVAZÍVNE SANAČNÉ TECHNOLÓGIE ODVLHČOVANIA MURIVA A MODERNÉ PRÍSTUPY K DIAGNOSTIKE VLHKOSTI

Anton Cvik, Patrik Šťastný [1]

Anton Cvik je doktorandom na Katedre technológie stavieb na Stavebnej fakulte Slovenskej technickej univerzity v Bratislave. V oblasti výskumu sa venuje problematike invazívnych sanačných technológií a hodnoteniu účinnosti odvlhčenia stavebných konštrukcií. Jeho dizertačná práca je zameraná na závislosť účinnosti odvlhčenia konštrukcie od využitia moderných invazívnych sanačných technológií. Patrik Šťastný pôsobí ako docent na Katedre technológie stavieb Stavebnej fakulty Slovenskej technickej univerzity v Bratislave. Vo svojom výskume sa venuje analýze vybraných protivlhkostných sanačných technológií a všeobecne sa zameriava na patológiu stavieb a vznik a sanáciu porúch konštrukcií z technologického hľadiska. Aktuálne je riešiteľom dvoch národných projektov.

Anton Cvik is a PhD student at the Department of Building Technology at the Faculty of Civil Engineering of the Slovak University of Technology in Bratislava. In the field of research, he deals with the issue of invasive remediation technologies and evaluation of the effectiveness of dehumidification of building structures. His dissertation thesis focuses on the dependence of the effectiveness of dehumidification of structures on the use of modern invasive remediation technologies. Patrik Šťastný works as a associate professor at the Department of Building Technology of the Faculty of Civil Engineering of the Slovak Technical University in Bratislava. In his research, he is devoted to the analysis of selected anti-humidity remediation technologies and generally focuses on the pathology of buildings and the emergence and remediation of construction failures from a technological point of view. He is currently the manager of two national projects.

[1] Adresa pracoviska: Ing. Anton Cvik, Ing. Patrik Šťastný, PhD., Slovenská technická univerzita v Bratislave, Stavebná fakulta, Katedra technológie stavieb Radlinského 11, 910 05 Bratislava
E-mail: anton.cvik@stuba.sk, patrik.stastny@stuba.sk

Abstract
The dehumidification of historic buildings represents one of the most complex challenges in building renovation. This paper first briefly presents the established Slovak framework for diagnosing moisture and classifying invasive dehumidification technologies as defined by Makýš (2018) in the monograph "Technology of Building Renovation", including the possibilities of determining mass and volumetric moisture content using invasive and non-invasive methods. Building on this basis, selected modern international approaches published between 2020–2025 are introduced, focusing on advanced moisture monitoring (Sensor Innovation, 2024), smart and hybrid dehumidification systems (Dantherm Group, 2025), and the use of digital tools and artificial intelligence to support decision-making. These approaches do not replace traditional invasive technologies, which often remain the most effective option where horizontal damp-proof courses are missing or defective, but can improve the timing, targeting and verification of remedial measures. The paper identifies research needs related in particular to the long-term evaluation of secondary anti-damp injection systems (Szemiot et al., 2023) and the energy efficiency of dehumidification strategies in historic masonry (Wasik & Łapka, 2023; Fraunhofer IBP, 2020).
Key words: dehumidification, invasive technologies, masonry, moisture diagnostics, building renovation

Abstrakt
Odvlhčovanie historických stavieb predstavuje jeden z najzložitejších problémov pri rekonštrukcii budov. Článok najprv stručne predstavuje ustálený rámec diagnostiky vlhkosti a klasifikácie invazívnych technológií odvlhčovania muriva podľa Makýša (2018) v monografii „Technológia obnovy budov", vrátane možností stanovenia hmotnostnej a objemovej vlhkosti pomocou invazívnych a neinvazívnych metód. Na tento základ nadväzuje predstavenie vybraných moderných medzinárodných prístupov publikovaných v rokoch 2020–2025, zameraných na pokročilé monitorovanie vlhkosti (Sensor Innovation, 2024), smart a hybridné odvlhčovacie systémy (Dantherm Group, 2025) a využitie digitálnych nástrojov a umelej inteligencie na podporu rozhodovania. Tieto prístupy nenahrádzajú tradičné invazívne technológie, ktoré v prípadoch chýbajúcej alebo nefunkčnej horizontálnej izolácie často zostávajú z technického hľadiska najúčinnejším riešením, môžu však zlepšiť načasovanie, cielenie a overenie ich účinnosti. Článok identifikuje potrebu ďalšieho výskumu, najmä v oblasti dlhodobého hodnotenia sekundárnych injektážnych clôn (Szemiot et al., 2023) a energetickej efektívnosti stratégií odvlhčovania historického muriva (Wasik & Łapka, 2023; Fraunhofer IBP, 2020).
Kľúčové slová: odvlhčovanie, invazívne technológie, murivo, diagnostika vlhkosti, obnova budov

Introduction
The dehumidification of historic buildings is among the most common and, at the same time, most demanding tasks in their renovation. Moisture in masonry causes not only aesthetic defects in the form of salt efflorescence, spalling plaster and changes in surface colour, but also leads to a reduction in the strength of materials, damage to structural elements, and a

deterioration of the indoor environment in terms of hygiene and user comfort (Makýš, 2018). In the case of historic buildings, these are often constructions without an original horizontal damp-proof course, or with damp-proof courses whose function has been significantly limited after decades or centuries (Szemiot et al., 2023).

In the Slovak context, a systematic framework for addressing the issue of structural dampness is provided by the monograph of Makýš (2018), which comprehensively describes the causes of dampening, methods of determining moisture, and the classification of remediation technologies according to how they act within the construction. Particular attention is paid to invasive technologies for creating additional impermeable layers and crystalline barriers, which, when properly designed and implemented, make it possible to effectively limit the capillary rise of moisture in masonry (Makýš, 2018).

This established framework is today complemented by modern diagnostic and management approaches that make use of continuous measurement of moisture and temperature, numerical modelling, and in some cases also artificial intelligence algorithms for evaluating trends and supporting decisions on the appropriate method of intervention (Sensor Innovation, 2024). The aim of the article is, against the background of the classical concept according to Makýš (2018), to present selected current possibilities for the diagnosis and management of masonry dehumidification, which may in the future complement and support the use of invasive remediation technologies.

Methodology

The methodological procedure of the article is two-stage. The first part briefly summarises the traditional framework for the remediation of damp constructions according to Makýš (2018), with a focus on the classification of invasive technologies and on the methods of determining the mass and volumetric moisture content of masonry using invasive and non-invasive measurements. The second part of the article presents selected modern international approaches published between 2020–2025, in particular in the field of moisture monitoring (Sensor Innovation, 2024), secondary anti-damp injection barriers (Szemiot et al., 2023), and the energy efficiency of dehumidification (Wasik & Łapka, 2023; Fraunhofer IBP, 2020).

The selection of current literature was carried out through a systematic search of the Web of Science, Scopus and Google Scholar databases and on specialist portals (AMS Surveys, 2024; Addamp Proofing, 2024), limited to the years 2020–2025. Key search terms included “masonry drying”, “moisture diagnostics”, “secondary anti-damp insulation”, “building moisture monitoring” and “energy efficiency of dehumidification”. When selecting the focus, emphasis was placed on works focusing on the combination of invasive and non-invasive methods of assessing the moisture of historic masonry and on longer-term monitoring of the effectiveness of remediation measures (Szemiot et al., 2023).

Framework according to Makýš (2018): moisture and invasive technologies

<u>Moisture in masonry and its determination</u>

In describing the dampening of historic masonry, Makýš (2018) starts from the classical physical mechanisms, such as capillary rise, absorbency, water vapour diffusion and condensation, while paying particular attention to the influence of moisture on material degradation and the formation of salt efflorescence. The quantification of moisture is based on the distinction between mass moisture content, defined as the ratio of the mass of water to the mass of dry material, and volumetric moisture content, related to the volume of the dry mass (Makýš, 2018).

Both invasive (destructive) and non-invasive methods are used to determine these quantities. Invasive methods include the gravimetric determination of moisture from masonry samples taken and dried to a constant mass, the carbide method based on the reaction of water with calcium carbide, and the taking of samples for salt content analysis (Makýš, 2018). Non-invasive methods mainly include electrical contact moisture meters (resistance and capacitance types), microwave techniques, and thermographic imaging of surface temperature fields, which indirectly indicate changes in the moisture regime of the construction (Makýš, 2018). Makýš emphasises the need to combine several methods and to interpret the results in the context of the structural design and history of the building.

<u>Classification of invasive remediation technologies</u>

Makýš (2018) divides the technologies for the remediation of damp buildings into several groups according to their building-physical effect, whereby invasive technologies mainly represent the group of technologies for creating additional impermeable layers and crystalline barriers, as well as selected electrophysical methods.

Technologies for creating additional impermeable layers are based on creating a mechanical barrier against capillary rise, typically by cutting into the masonry, driving in stainless steel sheets, or rebuilding the insulation joint (Makýš, 2018). When cutting into masonry, a cut is made in the bed joint, into which a waterproofing strip is inserted; Makýš distinguishes manual cutting with a hand saw (suitable for brick masonry 30–45 cm thick), cutting with a disc or chain saw, and the diamond-wire cutting method that is often used today, which allows even very thick masonry to be processed (Makýš, 2018). Working sections are carried out in an alternating sequence (1-3-5-2-4), and the masonry is temporarily secured by wedging and propping in order to maintain the stability of the construction (Makýš, 2018).

The driving-in of stainless steel sheets uses corrugated stainless steel sheets made of very hard steel, which are driven into the bed joint of coursed brick masonry using a special mechanical press. This method can only be used for coursed brick masonry up to a maximum thickness of 1 m (Makýš, 2018).

Rebuilding the insulation joint is the oldest method, which Makýš (2018) recommends mainly for monuments of vernacular architecture. The method consists of dismantling the masonry in working sections, inserting new waterproofing, and subsequently rebuilding the masonry.

Crystalline barriers form the second major group of invasive methods, in which an injection material is introduced into the masonry to create a hydrophobic or sealing barrier in the pore system of the masonry (Makýš, 2018). Implementation involves drilling holes about 3 cm in diameter, drilled at an angle of 15–45° into the wall, at a rhythmic spacing of 10–30 cm, followed by impregnation or pressure injection of a suitable preparation (Makýš, 2018). Makýš states that these barriers can be an effective solution where disc or wire cutting is not possible, while also drawing attention to the need for technological discipline and consideration of the heterogeneity of historic masonry.

Among invasive technologies, Makýš also includes selected electrophysical methods, such as galvano-osmosis and electro-osmosis devices, in which the effect of an electric field is used to transport moisture in masonry (Makýš, 2018). The use of these methods requires an expert assessment of their suitability with regard to the material and condition of the masonry, and their effect is often conditional on combination with other measures.

This framework of invasive technologies and moisture measurement, as defined in this way, represents a starting point in the Slovak context for the design of remediation for damp historic masonry, and forms the basis on which new diagnostic and management approaches can build.

Selected modern approaches to the diagnostics and management of dehumidification (2020–2025)

Smart monitoring and digital tools

In recent years, the field of continuous moisture monitoring in historic masonry has been developing significantly abroad, using a combination of sensor networks, wireless data transmission and advanced evaluation (Sensor Innovation, 2024). Modern systems enable long-term monitoring of relative air humidity, temperature, and often also the estimated moisture content in masonry, with the measured data processed in cloud applications and visualised in time and space.

These solutions can serve as an extension to traditional diagnostic methods and to invasive technologies by making it possible to more precisely determine in which parts of the construction and at what time an intervention is needed, and subsequently to verify its effectiveness across different seasons (Sensor Innovation, 2024). In some projects, the use of predictive models and artificial intelligence algorithms to estimate the future behaviour of moisture is also being trialled, which can contribute to better planning of maintenance and prevention.

Energy efficiency of dehumidification

Current studies pay attention not only to the technical effectiveness of remediation, but also to the energy demands of dehumidification processes (Wasik & Łapka, 2023; Fraunhofer IBP, 2020). Numerical analyses of masonry drying show that by optimising temperature and boundary conditions it is possible to reduce energy consumption while maintaining the required drying rate, which is particularly significant for the long-term use of technological equipment (Wasik & Łapka, 2023).

Fraunhofer IBP (2020), in its research into the drying behaviour of different types of masonry, demonstrated that the type of plaster has the greatest influence on the drying rate, which points to the need for a comprehensive approach that takes into account all layers of the construction.

Energy efficiency thus represents a supplementary evaluation criterion that extends the traditional assessment based on drying speed and the reliability of the barrier created. In the future, this criterion may influence the choice between different technical solutions, particularly for larger buildings and long-term renovation projects.

Secondary anti-damp injection barriers and their evaluation

International review studies focused on secondary anti-damp injection barriers in historic brick masonry point out that, despite the widespread use of injection technologies, empirical data on their long-term effectiveness remain relatively scarce (Szemiot et al., 2023). Studies document a significant reduction in moisture following the application of certain injection materials, for example paraffin- or silane-based products — Szemiot et al. (2023) recorded an average moisture reduction of 92% — but at the same time note that monitoring often lasted only a few months and that moisture conditions changed over time.

The authors state that “not enough research has been carried out to be able to conclude whether the chosen method is the best remedial solution” (Szemiot et al., 2023). This observation is significant given that Makýš (2018) states that crystalline barriers have “an insulating service life of, for example, 20 years”, yet empirical long-term studies confirming this service life in practice are still lacking.

The authors of these reviews recommend combining invasive and non-invasive methods for evaluating the effectiveness of barriers — from gravimetric and chemical analyses of samples taken to electrical and microwave measurements and numerical modelling of moisture distribution in masonry (Szemiot et al., 2023). Such an approach can help to better understand the behaviour of injection barriers in different types of historic masonry and in environments with elevated salt content.

Non-invasive technologies supporting renovation

Alongside invasive solutions, non-invasive or only minimally invasive technologies are also being developed internationally, which can in certain situations contribute to improving the moisture regime without intervening in the structure of the masonry (AMS Surveys, 2024; Addamp Proofing, 2024). One example is the use of adsorption dehumidifiers in combination with controlled ventilation, which made it possible to stabilise the indoor climate of a 130-year-old historic building in Copenhagen — moisture was reduced from 90% RH to 45% RH without any structural intervention in the masonry (Dantherm Group, 2025).

British professional sources emphasise that in historic buildings “breathability” — the vapour permeability of constructions — is crucial and must be respected when designing remediation (AMS Surveys, 2024). Addamp Proofing (2024) points out that “one-size-fits-all approach simply doesn’t work” and emphasises the need for individual diagnostics before any intervention.

These solutions are particularly interesting in situations where heritage protection is very strict, or where invasive interventions in masonry are limited for technical reasons. However, in cases of missing or damaged horizontal damp-proofing, they generally do not replace the need to create an additional barrier, but rather complement the overall strategy for reducing moisture and protecting the interior (Makýš, 2018).

Discussion

The traditional remediation framework according to Makýš (2018) provides a comprehensive system in which invasive technologies for creating additional impermeable layers and crystalline barriers play a key role, especially in historic constructions without a functioning horizontal damp-proof course. Modern diagnostic and monitoring approaches do not contradict this framework, but extend it with new tools that improve the awareness of designers and heritage conservators regarding the actual behaviour of moisture over time (Sensor Innovation, 2024; Szemiot et al., 2023).

In deciding on the appropriate method of intervention, the principle of gradual steps is increasingly being applied, whereby non-invasive measures and more detailed diagnostics are used first, and invasive interventions are chosen where other solutions do not provide a sufficient effect (AMS Surveys, 2024; Addamp Proofing, 2024). However, for historic masonry with missing or non-functioning damp-proofing, invasive methods such as wall-cutting or suitably designed injection barriers still remain, from a technical point of view, one of the most effective ways of limiting the capillary rise of moisture (Makýš, 2018), while modern monitoring can help to optimise their design and verify their long-term effect (Sensor Innovation, 2024).

Extending the evaluation criteria to include energy efficiency and environmental aspects brings a new dimension, especially in the long-term use of technological equipment and in complex renovations of larger groups of buildings (Wasik & Łapka, 2023; Fraunhofer IBP, 2020). At the same time, this points to the need for a more comprehensive evaluation of remediation interventions, which should include not only the immediate reduction of moisture, but also the long-term stability of the solution, operating costs, and the impact on the historic fabric.

Conclusion

The article presented the traditional framework for moisture diagnostics and invasive remediation technologies according to Makýš (2018) and, building on this basis, introduced selected modern approaches to the monitoring and management of the dehumidification of historic masonry. It was shown that invasive technologies for creating additional impermeable layers and crystalline barriers still retain fundamental importance today in addressing capillary dampness in historic constructions without a functioning damp-proof course (Makýš, 2018), while new non-invasive diagnostic and technological possibilities represent a suitable complement for better targeting and controlling the effectiveness of these interventions (Sensor Innovation, 2024; Dantherm Group, 2025).

Advanced monitoring systems based on long-term measurement and digital evaluation can help with the timely identification of risk areas, the optimisation of the timing of interventions, and the documentation of the behaviour of masonry after the remediation has been carried out (Sensor Innovation, 2024). At the same time, the importance of energy efficiency and environmental aspects is growing, extending the traditional criteria for evaluating remediation solutions (Wasik & Łapka, 2023; Fraunhofer IBP, 2020).

Vol. 14 (5), pp. 194-201

International review studies point out that, despite the large number of injection remediations carried out, there is still a lack of long-term quantitative data on their effectiveness in real historic masonry (Szemiot et al., 2023). A promising area for further research is therefore the comprehensive evaluation of invasive remediation technologies under the conditions of Central European historic buildings, combining classical measurements of mass and volumetric moisture with modern monitoring and numerical modelling (Makýš, 2018; Szemiot et al., 2023), with the aim of better quantifying their effectiveness, durability and energy demands.

This article was recommended for publication in a scientific journal Young Science by:
Ing. Milan Švolík, PhD.

References

1. AMS SURVEYS. 2024. Heritage House: How to Manage Damp in Old and Historic Buildings. [online]. [cit. 2025-11-12]. Dostupné na: https://amssurveys.co.uk
2. ADDAMP PROOFING SPECIALIST. 2024. Navigating the Challenges of Moisture Control in Historic Buildings. [online]. [cit. 2025-11-12]. Dostupné na: https://addamp-proofing.co.uk
3. DANTHERM GROUP. 2025. Sortedam Dossering: Tackling mould problems in a historic building. [online]. [cit. 2025-11-12]. Dostupné na: https://danthermgroup.com
4. FRAUNHOFER IBP. 2020. Drying behavior of masonry. [online]. [cit. 2025-11-12]. Dostupné na: https://ibp.fraunhofer.de
5. MAKÝŠ, O. 2018. Technológia obnovy budov: Ochrana a oprava spodných a obalových konštrukcií. Bratislava: Vydavateľstvo STU, 2018. 209 s. ISBN 978-80-227-4848-3.
6. SENSOR INNOVATION. 2024. Sensor Innovation uses AI to monitor humidity in buildings. [online]. [cit. 2025-11-12]. Dostupné na: https://sensorinnovation.no
7. SZEMIOT, M. et al. 2023. Assessment of the effectiveness of secondary anti-damp insulations in historic buildings. Scientific Reports, vol. 13, 2023.
8. WASIK, M., ŁAPKA, P. 2023. Numerical analysis on the energy efficiency improvement of drying extremely wet masonry walls. Science Direct, 2023.

Mladá veda
Young Science

ISSN 1339-3189