Water transport in materials of historical buildings

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Abstract. The historic buildings renovation is one of the unwritten obligations of every nation. In the territory of the Slovak Republic there is quantity of the historical buildings which are from different architectural periods, which we can find not only in the squares of the bigger cities, but also in a wide areas. The technical conditions of these buildings describe our relationship with which we look at them. At the present, many historic buildings are restored, but more are left untouched and without maintenance. Incorrect construction details, but also inappropriate additional building adaptation, cause degradation of the masonry and surface layers. Absence of the water-insulating waterproofing against capillarity allows the water to be transported into vertical structures and with it transport water-soluble salts from the subsoil. Increasing mass of the humidity by capillary transport and crystallization of water-soluble salts in porous materials causes visible defects on the surface of the structures. Laboratory measurement of the humidity and capacity of the water-soluble salts in a historic building point to the impact of the segmentation and using of the building. Different values of the taken samples define critical places that necessitate additional remediation. Suggestion of the remediation influences diversity of the materials which are used and their material characteristics. For the water transport analysis, it is necessary to know the transmission parameters of the water of the historical structures. Determination of the humidity coefficient is possible by the water absorption coefficient and the value of the capillary humidity. The measurement is carried out by an experiment of the unidirectional capillarity by the laboratory instrument.

1. Introduction
The most used building material in the history of constructing buildings was natural stone. When constructing buildings and cities, only the stones from surrounding areas which were influenced by geological composition were used. Sandstone from flysch belt and from sub-tatra group is used in eastern Slovakia. Absence of the water-insulation waterproofing against capillary water are enabling transport of water influenced by capillary forces in porous materials. Measuring of moisture and the content of water-soluble salts is done by laboratory measurement. Established values represent extensive damage in certain sections of the building. To be able to do proper constructional changes it is essential to know specific material parameters.

2. Stone as building material

2.1. Stone as building material in Slovakia
Natural stone was used in locations where suitable geological conditions were created. Hundreds of stone-pits surrounding cities show us, its massive usage in constructions. In the Middle Ages mining natural stone wasn’t limited by any means. Geological diversity of minerals on Slovak soil allowed mining of andesite (240 stone-pits), limestone (312), sandstone (336), travertine (87) and many others 0. The most used material was hewn and quarried stone. Foundations and cores of vertical constructions
were made from quarried stone and hewn blocks were generating only masonry cheeks. In the gothic ages, stone was used in great manner to decorate constructions too. Railings, window frames, cornicles and arches were made in stone workshops.

![Figure 1. Localization of historic stone quarries](image)

2.2. Sandstone as the main building material in eastern Slovakia

Layers of sandstone are located on Slovak republic’s territory mostly in areas of flysch belt, including Orava, Kysuce and north-eastern parts of Slovakia. This sedimentary mineral was mostly used for constructing buildings not for their properties, but for the lack of others, more suitable minerals. Sandstone was the most used mineral with and 336 registered stone-pits are proving it. The mining of the mineral raw materials was not limited by any legislation therefore stone-pits were created. Many of them were abandoned after mining all of the suitable material. The great amount of stone-pits created one big advantage, that is the ability to select minerals according to their quality. The most suitable sandstone was used mostly for decorative purposes.

2.3. Sandstone as the main building in Spiš region

The most exhibitory and known city in this area was Levoča, which contained many of building, carving and stone-cutting workshops. Levoča is the most sandstone city in Slovakia. Town houses, portals, churches, city hall, city walls, and also decorative features are built of sandstone. When entering the historical parts of the city you can see authentic fortifications from 13th century made of sandstone. Walls, towers and gates were built from quarry stone. Renewed city walls are creating the Middle age nature of Levoča, which contributed to inclusion of it to UNESCO World Heritage. The centre of historical part of the town is formed by rectangle square. The core of the square is surrounded by classic town homes. The second largest cathedral after St. Elizabeth’s Cathedral in Košice is located in the centre of the city. It is St. Jacob’s Cathedral. Its valuable decorative feature, the west entrance portal has been damaging for centuries. Today, the portal is renewed. From stonecutter’s and historical point of view was the most valuable and decorative feature the epitaph. This unique feature from sandstone was carved by Martin Urbanowitz. It is placed in front of the vestibule.
3. Moisture measurement and water soluble salt content

Increased moisture is one of the most common cause of damage of historical buildings, which is caused by absent waterproofing and incorrect constructing details. Stone as a building material is capillary active and allows transport of water and water-soluble salts in porous materials. Crystallization of salts causes degradation of plaster’s surface and carrier framework. For the correct design of the masonry, it is necessary to know the moisture content and content of water-soluble salts. The subject of the assessment moisture content and content of water-soluble salts is the town house on the St. Paul’s Square in Levoča. The building went through multiple constructional changes. In 1963 it was included to
national cultural monuments. It has two floors and a basement. The dominating building material was stone. Defects caused by moisture and water-soluble salts are visible by eye. For laboratory measurement, samples from defected areas were detracted. The valuating concerns front façade that is facing the square. Because of creating remediation measures, there is regulation STN P 730610, which states adequate and also increased content of water in constructions. The moisture of building materials is generally expressed as moisture mass.

![Figure 4. Town house in Levoča](image)

The addressed facade of the town house is oriented towards the east side of St. Paul’s square. Near to the house there is a road, a parking lot and a pathway which is connected to the building. There are visible defects of the front facade. Incorrect constructing details of sheet-metal lining of cornice, balcony and rain spout pipe are causing degradation of its surface design. The samples were detracted from the most affected parts. The content of water and the content of water-soluble salts were measured in laboratory.

| Measured value | (%) | MOISTURE CONTENT |
|----------------|-----|------------------|
| ≤ Mv ≤ 3,0    |     | VERY LOW         |
| ≤ Mv ≤ 5,0    |     | LOW              |
| ≤ Mv ≤ 7,5    |     | INCREASED        |
| ≤ Mv ≤ 10,0   |     | HIGH             |

Detracted samples were reviewed in terms of its pH values and content of water-soluble salts. The displayed classification is established according to WTA 2-9-04.

| Content of water-soluble salts | Cl – chloride (% | NO3 - nitrate (%) | SO4 – sulphate (%) |
|--------------------------------|------------------|-------------------|--------------------|
| LOW                            | < 0,2            | < 0,1             | < 0,5              |
| MEDIUM                         | 0,2-0,5          | 0,1-0,3           | 0,5-1,5            |
| HIGH                           | > 0,5            | > 0,3             | > 1,5              |
4. Results
Moisture content of detracted samples is demonstrated in Figure 5. The measured values according to STN P 73 0610 are in the first category, which means they have very low moisture content.

![Figure 5. Content of water in samples](image1)

Measured data of water-soluble salts are demonstrated in Figure 6. Detracted samples are indicating that they have average content of water-soluble salts. Two samples contain high content of chlorides. Four of the samples show too high values of nitrates, which originated from decay of organic materials. For setting the level of salinization it is important to set intensity of concentration, of any kind of it from our lab-discovered concentration. It can be set by measuring the concentration of sulphate, chloride or nitrate in reviewed samples.

![Figure 6. Content of water-soluble salts in samples](image2)

5. Conclusion
The most used building material in our history was stone. It was used as building material and also as decorative component. Sandstone was used for building purposes in eastern Slovakia. The most known sandstone rich cities are Levoča and Bardejov. Cathedrals, city halls and town houses are built exactly from this sedimentary mineral. The most occurring problem of historical buildings is transport of water from subsoil and water-soluble salts. Laboratory measurements of detracted samples from the front facade show very high volume of concentration of water-soluble salts in certain areas. Based on discussed measurement a sanitation of existing surface modification is needed.

6. References
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