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# TESTING OF MECHANICAL PROPERTIES OF NATURAL STONES USED AS A BUILDING MATERIAL

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**Abstract:** *Further presentation of some destructive and non-destructive methods for investigation of mechanical properties of natural stone quarried and used as a building material in Bohemia in the past is the aim of the paper. Tested samples were made both from virgin material from existing quarries (e.g. sandstone from Hořice) and from material got from historical constructions (various sandstones from the Charles Bridge in Prague), which was built-in for a long time. The flexural strength, the compressive strength and Young modulus were obtained from the basic destructive tests. Before these tests the identical samples were investigated non-destructively by ultrasound and so called peeling test so that the two ways of testing could be compared at the end.*

**Keywords:** ***Mechanical properties, non-destructive testing, natural stone, historical buildings***

## 1. Introduction

Historical buildings are part of cultural heritage and have to be maintained as the other structures to survive for next generations. Preliminary diagnosis operates with both destructive and non-destructive testing. Methods of non-destructive testing are easy to handle mostly and give quick results. Destructive testing operates with samples cut from the structure. Both ways of testing have their advantages and it is very useful to combine them.

## 2. Experimental work

Various types of sedimentary rocks, which have been found in Prague region in medieval ages, were tested. Virgin samples from existing quarries have been investigated so that new material could be compared with material already used in the structure; they were made from marlit stone, travertine and fine grained quartz sandstone from Hořice. Marlit stone is one of the most typical historical materials used in medieval ages in Prague and is composed of clay and calcareous elements with organic components. Travertine resists very well to weathering and nowadays it is one of the most popular natural stones used as a decorative element of facades. Sandstone from Hořice quarry is often used for reconstructions of historical buildings in Prague region. The other sandstone samples were made from stone blocks taken from the Charles Bridge. Light pinkish-grey hard porous arkose is coarse grained sandstone from Žehrovice. Hard sandstone with ferruginous cement from Petřín quarry is dark brown quartz stone with claystone fragments as accessories. Middle grained crumble porous sandstone from Nehvizdy quarry has horizontal layering conditioned by alternation of middle grained lamins and fine grained lamins.

The basic specimen dimensions were 50 mm x 50 mm x 300 mm; required for bending tests.. Compression test specimens were grinded from remaining beam halves after bending tests. Dimensions of these cubes were 50 mm x 50 mm x 50 mm, measured with accuracy of 0.1 mm. Specimens were conditioned for two physical states - the dry conditions and fully water saturated conditions. Before testing the specimens were stored in a climatic chamber at 70°C ± 5°C till an equilibrium state. Fully water saturated conditions were arranged by long-term storage of specimens in a container with water so that all the pores could be filled by water. The water absorption was natural because no vacuum or negative pressure was used.

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Ultrasonic tests and non-destructive peeling test were carried out on basic specimens before bending. The ultrasonic speed propagation was measured in longitudinal direction. Device used for testing was UKS 12 produced by Geotron Elektronik. Ultrasound velocity $c$ and dynamic modulus of elasticity $E$ have been calculated. For evaluation of peeling test the peeled off material was determined as the difference between the weight of the tape after removal from the surface and the weight of the clean tape before application. One measurement set consisted of 10 strips.

The flexural strength $R_{tf}$ and Young's modulus of elasticity has been calculated from the results of bending tests. The compressive strength $R_c$ was evaluated from compression tests. Loading devices were a load frame „WOLPERT" (max force 100 kN) and MTS 250 load frame (250 kN).

## 3. Results

Basic mechanical properties have been evaluated by both destructive and non-destructive methods for two conditions of the specimens. In *Tab. 1* there are summarized results for dry samples, peeling test included, and in *Tab. 2* there are results for fully saturated samples.

*Tab. 1: Summary of the results for dry material*

| Stone<br>Dry samples | Flexural strength<br>$R_{ft}$<br>[MPa] | Compressive strength<br>$R_c$ (Average value)<br>[MPa] | Peeling test<br>A<br>*1000 [g] | Ultrasound Speed Prop.<br>(Longitudinal direction)<br>[km/s] |
|---|---|---|---|---|
| Marlit stone | 12.55 | 52.50 | 2.04 | 3.70 |
| Travertine | 8.34 | 51.81 | 1.46 | 5.14 |
| Arkose | 3.58 | 26.70 | 3.10 | 2.64 |
| Hořice sandstone | 3.06 | 23.59 | 6.22 | 2.74 |
| Petřín sandstone | 2.72 | 19.37 | 1.73 | 2.93 |
| Nehvizdy sandstone | 0.68 | 7.93 | 63.07 | 1.83 |

*Tab. 2: Summary of the results for fully saturated material*

| Stone<br>Saturated samples | Flexural strength<br>$R_{ft}$<br>[MPa] | Compressive strength<br>$R_c$ (Average value)<br>[MPa] | Ultrasound Speed Propagation<br>(Longitudinal direction)<br>[km/s] |
|---|---|---|---|
| Marlit stone | 7.97 | 47.11 | 3.21 |
| Travertine | 8.27 | 39.80 | 5.38 |
| Arkose | 2.02 | 19.45 | 1.90 |
| Hořice sandstone | 1.80 | 22.76 | 2.19 |
| Petřín sandstone | 1.06 | 12.96 | 2.62 |
| Nehvizdy sandstone | 0.33 | 12.54 | 1.42 |

## 4. Conclusion

Various types of sedimentary rocks used as a building material in the past have been investigated. It has been observed that dry samples were more resistant to mechanical loading than saturated samples; both flexural and compressive strength was higher for dry samples. For all the materials with regularly distributed pores, not travertine, the ultrasound velocity was higher in dry samples than in saturated ones. Peeling test results confirmed that the materials with the lower compressive strength should have higher A-value that represents amount of peeled-off material. To compare destructive and non-destructive testing of natural stones, modulus of elasticity have been calculated. Peeling test could be used for preliminary testing of materials; it provides an estimation of material resistance to mechanical loading based on surface strength.