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WATER, FROST, AND FROST RESISTANCE

OF

NATURAL AND ARTIFICIAL BUILDING STONES

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by

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Translated by Mrs. Séverine Britt

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WATER, FROST, AND FROST RESISTANCE

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NATURAL AND ARTIFICIAL BUILDING STONES

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The worst enemy of construction engineering and of construction material is uncontrollable water, whether it be ground-, seepage-, rain-water, water of condensation, or melting snow and ice, exerting objectionable pressure upon tracks and roads. This applies as well to structures above the ground as to bridge piers and foundations, road construction, earthwork, etc.

In this respect, consideration will be given to insufficient sealing of masonry for dwellings, to defective waterproofing and draining of cellars, to damaged and pervious roofs, to leaky eaves, to insufficient or lack of waterproofing of stone arch-bridges, and to drainage of highways and railroads (tracks and cuts), etc. In some cases, the water involved is not soft but is rich in carbonic acid; then it is chemically active and has particularly great solvent power, the effect of which is frequently underrated and misunderstood.

If, in addition, frost forms, then water may, owing to the expanding action of the ice, act catastrophically.

Water and frost cause destruction that outweighs that of all other destructive agents acting on structures through oxidation and aging. More than bomb damages, water and frost have frequently caused the complete destruction of deteriorated buildings which could not be protected against them. Consequently, the architect and the construction engineer should pay particular attention to the problem of excluding water from all structural units in which it is liable to appear.

Considering the danger of water and frost, tests for water absorption and resistance to frost and weathering of natural and artificial building stones have been made for years with the idea of determining the suitability of these stones as building material. The procedures for these tests appear in numerous D.I.N. /Deutsche Industrie Normen: German Industry Standards/. Except for oxidation, completely impervious building materials and structural elements, such as window glass, copper sheet, rails, steel bridge girders, etc., all of which absorb no water, can be attacked by neither water nor frost. Resistance to frost and weathering is concerned primarily with other building materials that, under normal atmospheric pressure and conditions, absorb and retain more or less water. Physical data relating to these properties are the starting point for the study of frost and weathering resistance of building materials.

The simple absorption of water that takes place naturally and inevitably can be determined experimentally by immersing samples in water under normal atmospheric pressure for 24, 48, or 72 hours, until reaching constant weight (after previous desiccation of the samples). But this test is by no means a decisive and determinative basis for the estimation of resistance to frost and weathering of natural and artificial building stones used in exterior construction units. A much more accurate determination is obtained by the gradual absorption that is found by subjecting the sample to a vacuum and immersing it in water in a water-pressure container at 150 atmospheres. The total weight (again compared to dry weight) allows computing the so-called coefficient of saturation by its relation to simple absorption.

For instance, if a series of tests of 10 samples of natural and artificial building stones, immersed in water under atmospheric pressure up to constant weight, absorb a water content of 5 percent in weight, and if these samples, after being subjected to a vacuum and additional immersion in water at 150 atm. absolute pressure for 24 hours, absorb 2 percent more water in weight, consequently 7 percent in all, then the two values of 5 and 7 give a quotient, or coefficient of saturation S of 5:7 = 0.71. This coefficient of saturation signifies that the material in question, under normal atmospheric pressure and normal conditions, has only 71/100 of the pores filled with water and consequently 29 percent are free and do not contain water. If this material is exposed to freezing, the absorbed water will change into ice and expand approximately a tenth of the water volume. Therefore 0.71 + 0.071 or 0.78 of the pores will be filled with ice. There remain more voids (22 percent) available for further expansion of the ice. The bursting action of the ice can and will, therefore, be released in the free pores without causing any damage. These materials will and must, therefore, be and remain resistant to frost and weathering. Theoretically, a coefficient of saturation of 0.9 may be taken as the limiting value for the estimation of frost resistance. For more security, however, it is preferable to take a coefficient of 0.8 as the critical limiting value. All building materials with a coefficient from 0.8 to 0.9 are dubious, and those with a coefficient of 0.9 and higher must be rejected.

Alone, this method, which has previously been mentioned in DIN 52103 section 1C, and in DIN section B, gives clear and reliable physical results which can at any time be checked and proved, and which give a sure measure of the frost resistance of building materials. Moreover, this method has the great advantage of requiring only a small part of the time that was necessary for the so-called practical freezing test performed till now in a freezing chamber, and consequently, it is essentially cheaper.

However, if one now examines the current DIN standards for natural and artificial building stones, with reference to testing and estimating resistance to frost and weathering, it is found that there is no uniform understanding of the appropriate test and estimation of the resistance to frost and weathering; on the contrary, they differ very much from one another. Also there is no recognition that the quantitative determination of simple water absorption is meaningless in itself, and has a practical value only in connection with water absorption under 150 atm. water pressure, that is with the coefficient of saturation. Indeed, the reservation must be made that a low water absorption and, with it, a high density are very important considerations because a relatively high simple absorption permits one to infer a high pore volume and, in part, the various advantages related to it, as for instance in the great heat insulation property of bricks. The pore volume present in building materials can be determined still better from the difference between the apparent density and the true specific weight ascertained in the powder form.

For natural building stones, simple absorption is determined according to DIN 52103, section A, whereas DIN 52104 is used for the estimation of frost resistance. In this connection, as indicated above, the so-called practical, and commonly used frost-test in a freezing chamber, in accordance to DIN 52104-C is to be rejected because it gives only subjective conclusions. Instead, the method combining DIN 52104-A and B, and DIN 52103-C should be used.

In DIN 105 (building bricks), a simple water absorption of at most 6 percent by weight was required for hard bricks, 12 percent at most for hard-burned bricks, and at least 8 percent for facing bricks and building bricks. The basis on which these requirements were established is not given. According to DIN 105, the frost resistance, which, for hard bricks, hard-burned bricks, and facing bricks should have a strength of 150 kg/cm^2, must be tested and estimated by the frost test in the freezing chamber. This study and its possible results are no longer valid. Instead it is recommended to use the procedures of DIN 52103-C and DIN 52104-A and B, and then to estimate the frost and weathering resistance by computation of the coefficient of saturation.

In DIN 1115 (concrete tiles) in section 5.1, a value for frost and weathering resistance of concrete tiles is explicitly stated as a quality requirement. However, under section 5.4, it is said that impervious concrete tiles of the specified bending strength fulfill the currently accepted standard frost test, and that until a new freezing procedure is developed, they can be eliminated from the frost test requirement. This wording is unsatisfactory and should be replaced by the application of DIN 52103-C and DIN 52104-A and B. Surprisingly, the test for simple water absorption has been omitted in DIN 1115. The reason for this omission is even more obscure, especially as in DIN 1115, section 5.2, a result for water imperviousness is prescribed.

In DIN 456 (roofing tiles), tests for impermeability and frost resistance are required. It is mentioned that roofing tiles should not show any splintering in the freezing test. The frost resistance test of roofing tiles must therefore be made in a freezing chamber which, as stated above, is no longer suitable. Testing for simple water absorption is not mentioned in DIN 456. However, in the explanations of DIN 456, it is explicitly stated that it should still be investigated as to whether a specification on water absorption and water loss of roofing tiles is henceforth appropriate.

In DIN 4301 (Specifications on the quality of blast-furnace slag as road building material), under section B-5, the test of water absorption in accordance with DIN DVM 52103-1-A is required, by which the water absorption of the slag should amount to at most 3 percent of the dry weight. The frost-resistance of the blast-furnace slag, in accordance with DIN 52104-C, must be determined by test in a freezing chamber. It will be noted that no mention is made as to why blast-furnace slag should have a water absorption of only 3 percent in weight at most, and what this means in building technology. Moreover, the frost resistance of blast-furnace slag can no longer be adequately determined by tests within a freezing chamber.

Also in the testing and estimation of frost danger of clay, loess, and loam soils, as well as the frost resistance of outer plasters, flooring plasters, flagstones, wall tiles, high-tension insulators, and concrete products, etc., which are exposed to freezing, a reliable estimation of frost and weathering resistance is possible by determining the

the coefficient of saturation. Particularly for building materials that are almost impervious or considered as such, but really have thin capillary pores or fine punctures and fissures, and hence are especially susceptible to water and frost, the coefficient of saturation provides a very sensitive and reliable indicator.

The stone-testing committee of the Road Research Society, nevertheless, has drawn the necessary conclusions, and discarded the so-called practical frost test procedure in accordance with DIN 52104-C for the testing and estimation of natural stones to be used in road construction. In view of this, it is difficult to understand why the builder or the material testing organization should retain the frost test procedure in a freezing chamber and continue to apply it. That the DIN standards for this or that building material still prescribe the freezing-chamber test for frost resistance and that this requirement has not been changed yet (owing to the difficulty in changing DIN standards), and therefore still is to be considered as obligatory, can neither deceive anyone on the unreliability and inadequacy of the freezing-chamber test, nor convince anyone of its usefulness.

A freezing chamber in a testing laboratory, therefore, has but museum value today. The results obtainable with it are to be considered positively misleading. Consequently, the freezing-chamber test is a failure. On the other hand, frost resistance by means of determining the coefficient of saturation, which is physically checkable, and is conclusive in its results, gives convincing and reliable conclusions. Henceforth, one can and should use only the coefficient of saturation to test and estimate the frost resistance of natural and artificial building stones.

The particular value of this process is that it is generally suitable for all building stones with regard to the testing and estimation of frost resistance.