Draft NORDTEST METHOD

NATURAL BUILDING STONE: Test for bowing of cladding panels

1 SCOPE

This method describes a laboratory procedure for determining the potential of bowing of natural stone panels intended for building facades. Some varieties of marble have been known to cause pronounced bowing combined with strength loss when panels have been exposed on a façade. The method shall therefore be used to select natural stone types that are fit for cladding purposes, without demonstrating this phenomenon.

2 FIELD OF APPLICATION

The method is used for indicating thermal and moisture induced bowing of various natural building stones, especially carbonate rocks such as marble and limestone.

3 REFERENCES

[1] Schouenborg, B., Grelk, B., Brundin, J-A. & Alnæs, L., SP RAPPORT 2000: 28 Nordtest project 1443-99: Buktningsprovning av marmor för fasadbeklädnad (Bowtest for façade panels of marble).
[2] prEN 12670 - *"Terminology of Natural Stone"*
[3] prEN 12440 - *"Denomination of Natural Stone"*

4 DEFINITIONS

The same definitions as in NT BUILD **XXXX** (FIELD METHOD FOR MEASUREMENT OF BOWING OF CLADDING PANELS) apply.

Bowing: In this test method, bowing is used as a term for a slab that has changed from an original flat and plane shape to a curved or dished shape in a concave or convex direction. Other terms commonly used for the same phenomenon are warping and dishing.

Concave: Centre part of the specimen is bowing upwards, away from the moist substratum. Compare NT BUILD **XXXX** where the centre part of the panel is facing inwards (to the façade).

Convex: Centre part of the specimen is bowing towards the moist substratum. Compare NT BUILD **XXXX** where the centre part of the panel is facing outwards (away from the façade).

Object testing: Testing of panels taken directly from the production of cladding elements or from buildings.

5 SAMPLING

The method of sampling shall be stated in the test report and shall be chosen so that the samples are representative of the batch to be tested. For material characterisation purposes samples shall be selected from three perpendicular orientations (e.g. parallel, normal and perpendicular to foliation). For "object testing" it is sufficient to test one set of samples with the same orientation as the slabs to be used on the façade.

One test set consists of five specimens of size 400 mm by 100 mm, thickness as in use. For material characterisation the specimens shall have a thickness of 30 mm. The specimens shall be randomly chosen for the tests. At least one side of the samples (the side exposed to moisture) shall be smooth but not polished.

6 TEST METHOD

6.1 Principle

This laboratory method determines the bowing potential of natural building stones to be used as exterior cladding panels.

The bowing is measured on test samples exposed to one-sided moisture and infra-red heating on the other side. The temperature interval is from 20 to 80 °C, one cycle each 24 hours.

The moisture gradient is produced by letting the samples rest on a wet bed of sand that gradually dries under the influence of the infra-red heater. The temperature of the sand is not controlled by other means than the temperature of the laboratory, i.e. 21 ±2 °C.

6.2 Equipment

- A suitably sized, non-corrosive container for water immersion of the specimens.
- A thermometer at least ranging from 15 to 85 °C, with a tolerance of ± 2 °C.
- A watch or a timer.
- A container to moisten the specimens on one side and to expose them to heating on the other side (se example in figures 1 and 2).
- Sand to place the specimens on in the container above. No specification on the sand other than a capillary suction above the height of the thickness of the sand bed.
- Radiant heating devices, capable of keeping the specimens surface at 80 °C.
- A "bow-test rig" for measuring the amount of bow (see example in figure 3 and 4). The dial/digital gauge for measuring the amount of bow shall be readable to the thousands of one mm. It shall have an accuracy better than ± 0,01 mm.
- A thermometer capable of measuring the surface temperature of the specimens.

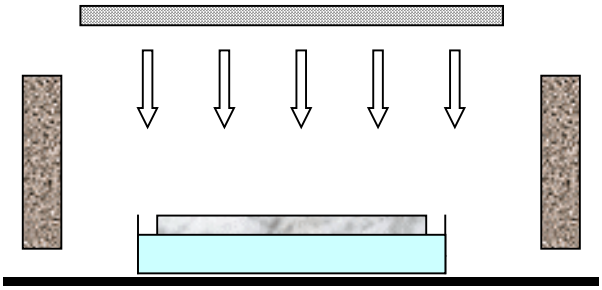

Figure 1. Principle sketch of an insulated container for testing the potential bowing properties of natural stone. The test specimens are placed in a pan, on top of a sand bed. The heat is distributed from above. The walls are preferably insulated.

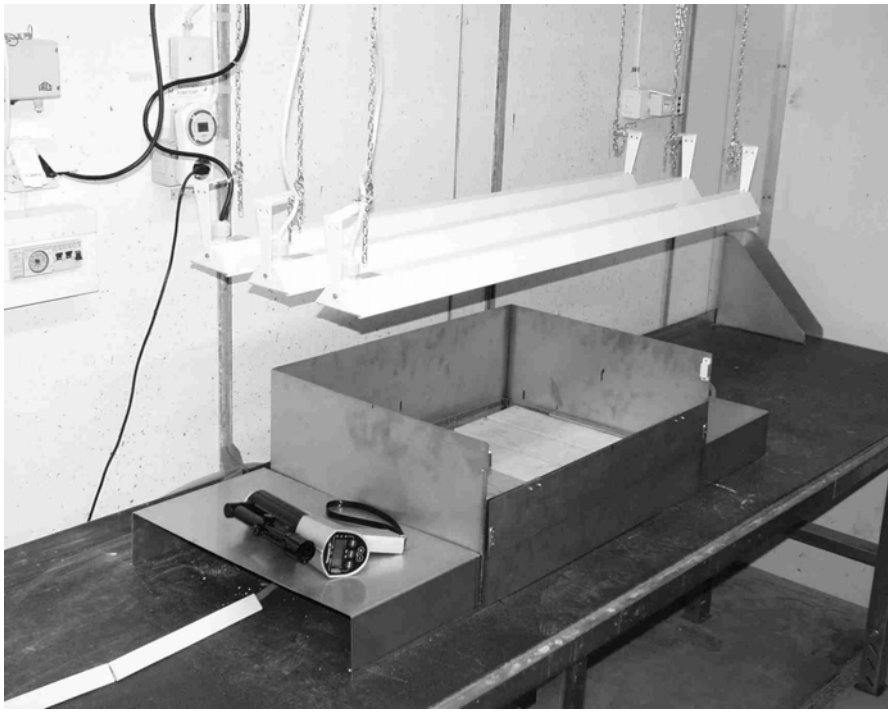

Figure 2 A. Test container with infra red heating lamps above.

Figure 2 B. Inner pan with sand bed and a water hose. Here complemented with an adjustable water level outlet.

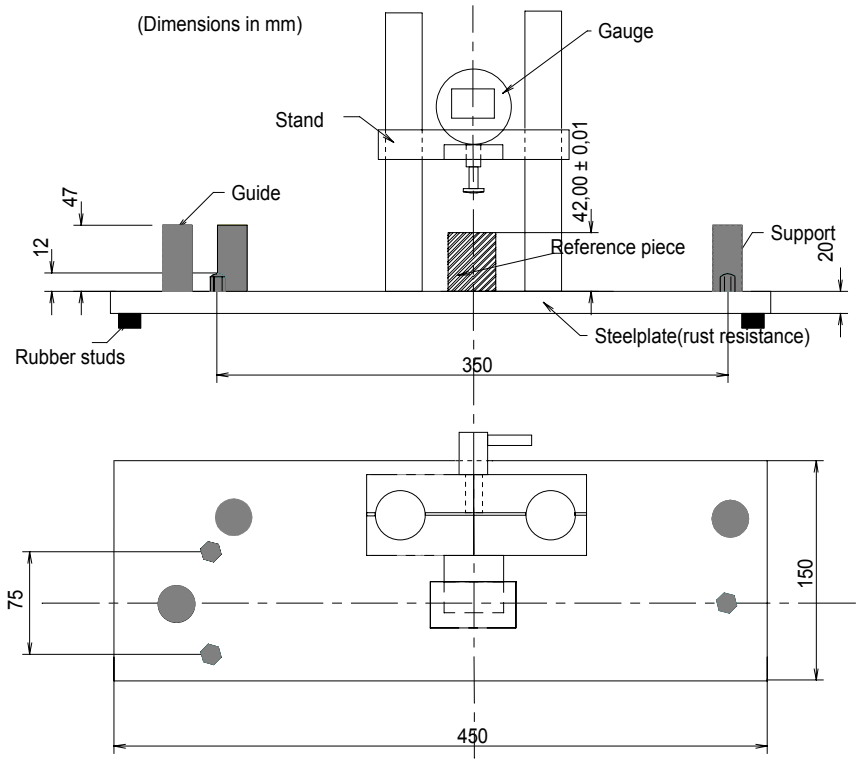

Figure 3. Principle drawing of a bow-test rig.

Figure 4. Example of a bow-test rig with a digital gauge and a reference cylinder for zero setting. The reference piece (a cylinder) is preferably made of invar steel and has a height of 30 mm, i.e. the same as the thickness of the specimens.

6.3 Pre-conditioning of test samples

All loose material shall be washed from the surface of the specimens using tap water.

Dry the specimens in a ventilated oven at a temperature of 60°C ± 2°C until a constant mass is reached. Constant mass is here defined as when the difference between two weighings, at an interval of 24 ± 2 hours, is not greater than 0.1%.

After drying, cool the specimens to room temperature 20°C ± 2°C. Each specimen is then labelled with a durable marking.

Each specimen is placed in an open container, partly immersed in distilled or filtered water to a depth of 10 mm ± 2 mm below the top of the specimen. The specimens are placed in the container at a distance of minimum 5 mm from each other and the distance to the sides of the container shall be at least 10 mm. Alternatively, the specimens may be placed in a single container provided that there is a minimum of 10 mm between the specimen and the sides of the container. The specimens shall be kept in the container for 24 hours at a water temperature of 20 ± 2 °C.

6.4 Test procedure and data processing

Before the specimens are exposed to temperature cycling, the difference in height between the top surface in the middle of the specimen (h) (see figure 3) and the reference cylinder is measured with an accuracy of ± 0.01 mm.

The container with the specimens is placed in an open insulating box under a group of radiant-heating devices (see example in figure 2 A). The heaters are placed approximately 0.5 m above the specimens. A temperature-measuring sensor is placed at the surface on top of one of the specimens. The heaters shall be arranged or adjusted by a regulator to provide a maximum surface temperature of 80°C ± 2 °C on top of the specimens at the hottest stage of the temperature cycling. Check that the heat is evenly distributed by placing the temperature sensor on different places in the container.

The raise of the surface temperature of the specimens from 20°C ± 2 °C to 80°C ±2 °C shall take place in not less than 1 hour and not more than 3 hours. The maximum temperature shall be obtained for 3 hours. The heater is then switched off, and the specimens are left in the container for at least 16 hours to be cooled down to ambient temperature (20°C ± 2°C).

Before each temperature cycle (2 ± ½ hours), it is necessary to remoisten the specimens by filling the container with distilled or filtered water in such a way that the specimens once again are partly immersed in water to a depth of 5 - 10 mm.

After each temperature cycle (approx. 22-24 hours) the change in height (h) of each specimen is measured at a temperature of 20°C ±2 °C. After the 10th cycle, measure the change in height every second cycle.

At least 40 cycles shall be carried out. After the last temperature cycle the height (h) is determined on both sides of the specimens to ensure that the result does not represent a volume increase due to immersion in water but pure bowing. Any such volume expansion shall be subtracted from the final bow result.

The magnitude of bowing is calculated as the difference between the first gauge reading and the final reading divided by 350 mm, i.e. the length between the supports under the specimens.

$$\text{bowing} = \Delta h / L \text{ (length)} \quad \text{mm/m}$$

Δh: Change in height in mm (after 40 cycles)
L: Length between the supports (0.35 m)

6.5 Applicability

The validation of the test method relies on the fact that stone types that show bowing damages on building facades also bow with this test. Stone types included in the test that are not known to have produced bowing on facades (e.g. granite and limestone) do not bow in the test.

Inter-comparison trials have not been performed. The precision of the test therefore remains to be established. To this date only repeatability (r_1) figures exists from measurements of parallel samples in one laboratory, see below.

6.6 Uncertainty

The precision data presented are preliminary and have been obtained within the Nordtest project, in which some varying procedures have been used.

r_1 is here calculated as 2,78 times the pooled standard deviation (s_1) of 3 marble types and one limestone. The test of each stone type was performed on 4 – 6 test specimens. s_1 was determined to 0,025 and r_1 to 0,07 mm.

6.7 Test report

The test report shall include the following information (when relevant)

a) Name and address of the testing laboratory
b) Identification number of the test report
c) Name and address of the organisation or the person who ordered the test
d) Purpose of the test
e) Method of sampling and other circumstances (data and person responsible for the sampling)
f) Name and address of the manufacturer or the supplier of the tested object
g) Name and other identification marks of the test specimens
h) Description of the test specimens
i) Date of supply of the test specimens
j) Date of test
k) Test method
l) Condition of the test specimens (i.e. orientation of stone fabric in relation to the test object and the applied force), environmental data during the test if relevant (temperature, RF etc.)
m) Any deviations from the test method
n) Test results (in SI units), see section 6.4
o) Statement about the uncertainty of the test results
p) Date and signature