Česká společnost pro nedestruktivní zkoušení materiálu
37. mezinárodní konference **DEFEKTOSKOPIE 2007**
Praha, 7. - 9. 11. 2007

NONDESTRUCTIVE TESTS OF PLASTERS

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ABSTRACT

This paper presents a case study of the investigation of plasters by means of the ultrasonic technique are presented. One of the major factors affecting the quality of plasters is their compressive strength and modulus of elasticity. Neither too high nor too low plaster strength is recommended. Too strong plasters crack, fracture or come off the base. Whereas too weak plasters crumble or fall off the base. In the case of external plasters, it is important that their compressive strength be not higher than that of the plaster base. The actual strengths of plasters on selected building structures were determined on the basis of the ultrasonic test results presented here. The plaster strengths were much higher than the base strengths, which caused the destruction of the plasters. Thanks to the ultrasonic technique, the plastering contractor can check whether the plaster applied is of good quality or whether measures should be taken to improve its quality before the plaster undergoes damage or destruction.

Keywords: non-destructive test, ultrasonic technique, strength, plaster, construction

1. INTRODUCTION

One of the major factors affecting the quality of plasters is their compressive strength and modulus of elasticity. Neither too high nor too low plaster strength is recommended. Too strong plasters are susceptible to cracking resulting in a network of cracks. Whereas too weak plasters crumble and fall off the base. In the case of external plasters, when the plaster's elasticity and thermal deformability moduli much differ from those of the base, the plaster often loosens and falls off.

The pull-off test or the Bond test, in which steel disks glued to plaster are pulled off by means of a hydraulic servomotor, is used to determine the adhesion of plasters. But on building sites still rather crude tests, such as tapping, scratching and macroscopic surface evaluation, are used.

Minimum adhesion requirements are set down in specifications [1]. For example, the minimum adhesion should be: 0.010 MPa for lime plaster, 0.025 MPa for cement-lime plaster and gypsum-lime plaster, 0.040 MPa for gypsum plaster and 0.050 MPa for cement plaster. In addition, the compressive strength of external plasters should not be higher than that of the plaster base.

The destructive method is used in the laboratory testing of plasters. 40×40×160 mm beams are made from mortar and subjected to testing in a strength tester. This way of testing is laborious and one must wait long for the results (the mortar needs to cure and it can be tested only when it is in the plastic phase). Hardened mortars on walls or ceilings are not tested since their thickness (usually 10-15 mm) is insufficient for carrying out mechanical tests. Nondestructive techniques, particularly the ultrasonic technique using surface waves, may be helpful in such cases.

2. PLASTER TESTING BY MEANS OF ULTRASONIC SURFACE WAVES

When a plaster has a much higher strength than that of the base, a characteristic network of cracks (fig. 1) forms on it.

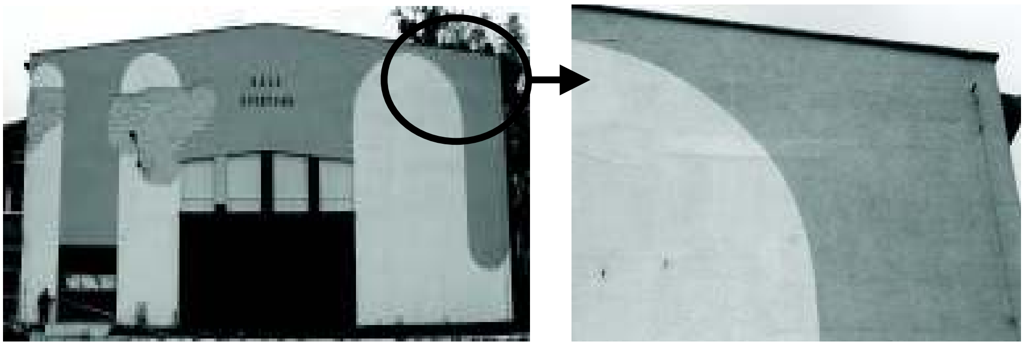

Fig. 1. View of part of industrial building (left) and close-up of plaster. Clearly visible network of cracks (right).

Questions about the strength of the mortar from which the plaster was made most often arise when some damage, e.g. plaster cracking or flaking, occurs (figs 2 and 3).

Fig. 2. Cement-lime plaster coming off gas concrete wall in area of few m^2.

Fig. 3. Cement-lime plaster and mascarons falling off ceramic brick wall in area of 1.5 m^2.

Using point-contact exponential heads one can precisely measure the velocity of the surface wave excited at the head/material contact [2, 3]. The measuring system used for plaster testing is shown in fig. 4.

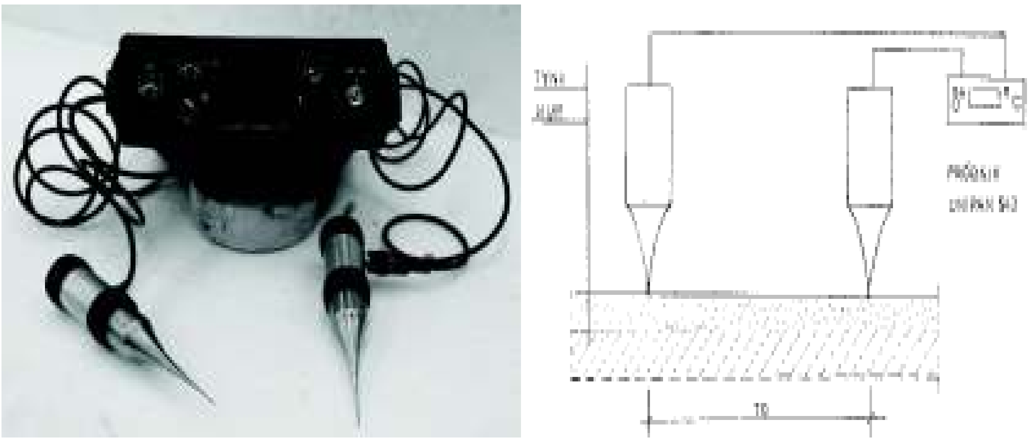

Fig. 4. Measuring equipment and scheme used for plaster tests.

Several measurements were carried out in different areas of the wall and the plasters which had fallen off the wall. The measurements were performed along constant measuring path j *l* = 70 mm, using 100 kHz exponential heads working in tandem with a UNIPAN 543 digital meter. An exponential function based on in-house tests [3, 4] was adopted as the scaling curve for cement mortars ranging from weak (1:8 cement/sand ratio) to strong (1:3). The following relation was obtained:

$$f_c = 0.659 e^{1.44 C_p} \qquad \text{[MPa]} \qquad (1)$$

The relation was determined for cylindrical specimens with their diameter and height equal to 80 mm. In accordance with current Polish standard PN–B-03002:1999 and mortar testing standard PN–85/B-04500, the strength of mortars is determined using 40×40×160 mm beams. The correction factor is 1.5. Ultimately the scaling curve has this form:

$$f_c = 0.988 e^{1.44 C_p} \qquad \text{[MPa]} \qquad (2)$$

Six measurements were performed for each investigated area and the average was calculated. Exemplary results are shown in table 1.

Table 1. Average compressive strengths of cement-lime mortar in investigated areas located few meters apart.

Zone	Area No.	Average compressive strength f_{cav} [MPa]	Average compressive strength in zone f_{cav} [MPa]
A	1 2 3	11.0 7.6 9.0	9.2
B	1 2 3	10.9 9.7 10.4	10.3
C	1 2 3	10.3 10.6 10.0	10.3
D	1 2 3	12.1 12.6 12.6	12.4

3. ANALYSIS OF PLASTER/BASE INTERACTION

The best plaster/base interaction conditions occur when the physicochemical properties of the bonded materials are the same or very similar. For this reason cement-lime plaster well interacts with brickwork or with concrete elements. The model external plaster is plaster whose strength is very close to that of the wall material but slightly lower in the following way: if the plaster is made up of a few coats (e.g. three-coat plaster), the first coat from the wall (the rendering coat) has strength equal to that of the base and each next coat has a slightly lower strength.

It emerged from the obtained results that the mortar had a very high strength of 9.2-12.4 MPa as compared with the strength of gas concrete 0.5, ranging from 3.0 to 4.5 MPa. It was found that the strength of the plaster was about three times higher than that of the base and the difference between the elasticity moduli was even greater. The elasticity modulus for the gas concrete wall is E = 800 f_k where:

$$f_k = f_b^{0,65} = (\eta \cdot \delta \cdot f_b)^{0,65} = (0,8 \cdot 1,0 \cdot 3,0)^{0,65} = 1,76 \text{ [MPa]} \quad (3)$$

Thus the elasticity modulus for the gas concrete wall is E = 800·1.76 =1413 MPa and for plaster with a strength above 10 MPa it is in the order of 10-20 thousand MPa. Such materials cannot interact well. In order to show it let us examine the physical phenomena which take place in 24 hours. At night the temperature of the plaster and of the gas concrete (the base) falls down to, e.g. 10°C. In cloudless weather the plaster very quickly heats up to a temperature of, for example, 30°C as a result of insolation. Since the gas concrete base is a heat-insulating material its initial temperature remains at 10°C for quite a long time. Thus the temperature difference amounts to Δt = 30 – 10 = 20°C. As a result, the plaster on the 24.7 m long gable wall will elongate relative to the base by:

$$\Delta l = 2470 \cdot 20 \cdot 1 \cdot 10^{-5} = 0.49 \text{ cm} \sim 5 \text{ mm}. \quad (4)$$

At such a small temperature difference the plaster would elongate by about 5 mm if it were free (not bonded to the wall). But since it is bonded, stresses will arise in the plaster and in the base:

$$\sigma = \frac{\Delta l \cdot E}{l} = \frac{0.0049 \cdot 18000}{24.7} = 3.6 \text{ MPa}. \quad (5)$$

The stresses cause the shearing of the contact between the plaster and the gas concrete. Actually the strains and stresses may be much higher since Δt can be much larger. As one can see they resulted in gas concrete shearing and plaster bulging (buckling since the plaster coat is strongly compressed). This process recurs many times (even during the day) and with wind suction added it results in the plaster coming off the wall.

When the façade is heated up for a longer time by sunlight, also the gas concrete base layer's temperature will increase, the more so that it is separated from the bearing wall by a heat-insulating layer. As the temperature increases the concrete base layer elongates. This caused the cracking of the plaster on the longitudinal wall (fig. 5).

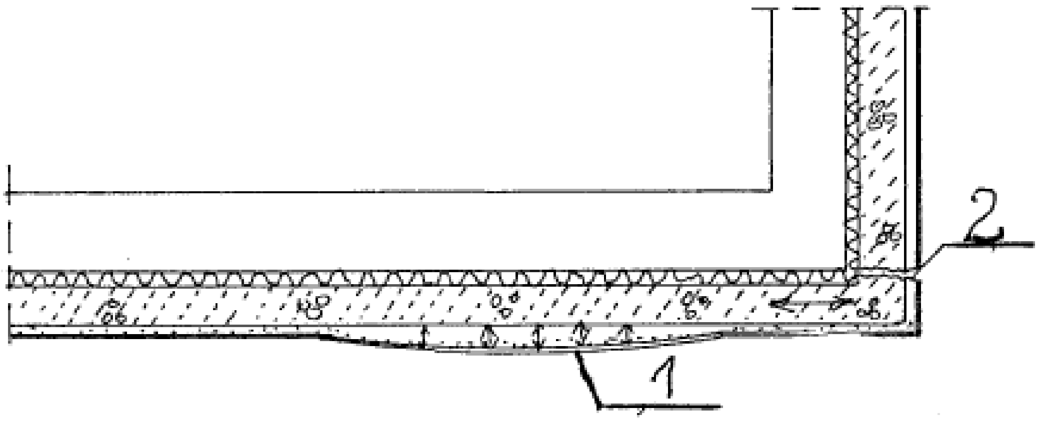

Fig. 5. Damage to plaster caused by plaster elongation relative to still cool base 1 and elongation of gas concrete layer after longer period of heating 2.

In order to prevent the above situation a well prepared design should include directions for applying plaster, including the latter's strength and dilatation in the wall. Also each of the plastering contractors should know this information.

4. CONCLUSIONS

The nondestructive tests of plasters and their results provide an explanation why the plaster in the investigated building structures does not interact well with the wall. The fact that the plaster deformed differently than the wall resulted in the shearing of the latter's thin layer of cellular concrete whereby the plaster fell off the wall.

The ultrasonic investigations made it possible to determine the facts (the actual strengths) and confirm the theoretical considerations. What is more important, the plastering contractor can check whether the plaster applied is of good quality or whether measures should be taken to improve its quality before the plaster undergoes damage or destruction.

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