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SHORT REPORT

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CRACK-SAFE RENDERING ON LIGHTWEIGHT MASONRY

1 THE PROBLEM AND THE AIM IN VIEW

Lightweight masonry is a significantly “softer” background than normal masonry of units with higher raw density and compressive strength. The rendering must be adapted to the properties of the masonry, in which the background must also fulfil specific requirements. For over 10 years lightweight renders have been available, which are largely adapted to the background, lightweight masonry. Nevertheless there is an appreciable number of cases of cracking damage of rendering, which may affect the functional performance of the “external skin” to varying degrees – particularly in regard to weathering influences. The expenditure on maintenance is usually considerable and results in additional building costs. In order to obtain safety of execution and freedom from damage, definite, practice-related and quantified evaluation criteria are needed, giving the conditions to ensure that the system rendering and lightweight masonry remains with maximum possible safety free from damaging cracks. These are cracks with crack widths r_b larger than about 0.2 mm. Such cracks are normally damaging as moisture can penetrate through them to the background.

Damaging cracks are produced when the tensile force of the rendering being released cannot be absorbed by the background. The background is then unable to make a fine distribution of the cracks in the rendering. In order to avoid these damaging cracks a co-ordination of the render and the background, lightweight masonry, is required. In order to evaluate the damage-free deformation compatibility of rendering on lightweight masonry, a simple calculation model should therefore be prepared, with the help of which it is possible to determine which properties the render on the background should have in order to avoid damaging cracks. Vice versa, the calculation model however should also afford an opportunity for a possible adaptation of the properties of the background for known properties of the rendering.

2 PROCEDURE TO BE FOLLOWED

The Research Project is subdivided into 3 parts. In the first part on the basis of a literature search a simplified calculation model was drawn up with which a simplified estimate can be made of the risk of damaging cracks in the rendering. As a realistic evaluation of the cracking risk is possible only with deformations of the render on the background effectively occurring, and the mechanical properties of the render on the background, and of the background, in the second part practical tests were carried out on renders on the background. In these, as expected, a relationship was determined between the final shrinkage value of flat prisms taken from the rendered surface of rendered masonry units and the moisture content on removal. Together with the shrinkage of render on the background it was possible with the criteria drawn up and the specific properties of the render on the background to carry out a more appropriate estimate of the risk of damage than with the property values of the render mortar. In the third part of the Research Project all properties to be found in the literature of render with and without contact to the background and also the properties of the masonry units were compiled and evaluated. On this basis the procedure was drawn up for the co-ordination of render and background.

3 APPROACHES FORMULATED FOR THE EVALUATION OF SAFETY FROM CRACKS

For many years there has existed in the literature /1/ only one approach with which the safety from cracking of the rendering can be approximately evaluated. With this approach (see Equation (1)) under complete prevention of deformation the tensile stresses occurring in the rendering as a result of shrinkage and change of temperature, are placed into relationship to the tensile strength of the render, taking the relaxation into account.

$$K_R = \frac{\beta_Z}{E_Z \cdot (\varepsilon_S + \alpha_T \cdot \Delta T) \cdot \psi} \qquad (1)$$

β_Z	tensile strength of the render
E_Z	tension modulus of elasticity of the render
ε_S	shrinkage of the render
α_T	coefficient of thermal expansion of the render
ΔT	temperature difference between background and render
Ψ	coefficient of relaxation

With crack characteristic values of K_R less than 1 the tensile stresses occurring in the rendering are less than the tensile strength of the rendering, i.e. no cracks occur in the rendering. If the crack safety characteristic value is greater than 1, the tensile stresses exceed the tensile strength. The risk of cracking in the render increases with a greater characteristic value and vice versa. The K_R-value however goes from a complete prevention of deformation and is therefore well on the safe side. More appropriate the prevention of deformations of the rendering by the background can be taken into account with evaluation of the risk of cracking with the prevention degree R.

$$R = \frac{\varepsilon_{s,free} - \varepsilon_{s,prev}}{\varepsilon_{s,free}} \qquad (2)$$

$$\varepsilon_{s,\sigma} = \varepsilon_{s,free} - \varepsilon_{s,prev} \qquad (3)$$

$\varepsilon_{S,\sigma}$	stress-relevant shrinkage of the rendering
$\varepsilon_{S,free}$	free, non-prevented shrinkage of the rendering
$\varepsilon_{S,prev}$	prevented shrinkage of the render on the background

R is calculated from the ratio of stress-relevant shrinkage $\varepsilon_{S,\sigma}$, i. e. the deformation, from the stresses resulting in the rendering (difference from free shrinkage and prevented shrinkage according to Equation (3)) and free, non-prevented shrinkage of the rendering. With complete prevention of the shrinkage by contact with the background ($\varepsilon_{S,prev} = 0$) the degree of prevention equals 1, this means that the tensile stresses result from the entire shrinkage $\varepsilon_{S,free}$. In the case of free deformation, i.e. when free shrinkage of the rendering and the background are the same size ($\varepsilon_{S,prev} = \varepsilon_{S,free}$) the degree of prevention amounts to 0. The K_R-value extended by R, by neglecting different thermal expansions, which owing to the slight differences between the temperatures and the coefficients of thermal expansion of rendering and background are small, is given as

$$K_R = \frac{\beta_Z}{R \cdot E_Z \cdot \varepsilon_S \cdot \psi} \tag{4}$$

An estimate of cracking risk is possible with this value, so long as R is known. R is determined most appropriately by tests on the render from the background and on the render on the background. An evaluation of the risk of <u>damaging cracks</u> is not possible however with the K_R-value. With the assumption that damaging cracks occur when the tensile force in the rendering with cracking is greater than the tensile resistance of the background, makes the following criterion be applied

$$\beta_{Z,PG} \cdot d_{PG} \geq \beta_{Z,P} \cdot d_P \tag{5}$$

$\beta_{Z,PG}$ tensile strength of the background
d_{PG} thickness of the shells of the perforated masonry units resp. the effective thickness of solid masonry units
$\beta_{Z,P}$ tensile strength of the rendering
d_P thickness of the rendering

If the result of the K_R-value (Equation (4)) is an increased risk of cracking, the damage potentiality must be estimated with Equation (5).

4 SUMMARY

Within the scope of the Research Project /2/ criteria related to practice should be derived with which the crack-free compatibility of the rendering and the background can be evaluated.

In the first part of the work a simplified calculation model for the estimation of crack safety of render on lightweight masonry was developed. In the second part tests were carried out on render with and without contact with the background and on the background, in order to determine the starting values for the calculation model. Here the essential mechanical and physical properties were determined of the render tested without contact and with contact with the background, the shrinkage of render from the background and the shrinkage of render on the background. By removal of render prisms at the age of 2 or 3 days from the rendered units the largely free, non-prevented shrinkage of the rendering was determined. From the data determined the stress-relevant amount of the shrinkage expansion values could be estimated, which is included in the calculation model. In the third part of the work for compiling essential property values of render and background for the formulation of requirements of the render or of the background, all the literature references covered in the Institute of Building Materials Research were collected and evaluated in a databank.

The essential results can be summed up as follows:

- The crack safety characteristic value K_R known up to now was extended with the degree of prevention R, with which crack safety of the rendering, taking into account the contact with the background, can be appropriately estimated. The degree of prevention R derived from the test values is however only appropriate here for the types of masonry units tested. In order to obtain a conclusion on other masonry units, further more extensive experimental tests are required.
- With the help of a further more extensive criterion the risk of damaging cracks can be estimated, by comparing the tensile strength of the rendering with the tensile strength of the background.
- A relationship was indicated between the final shrinkage $\varepsilon_{S,\sigma,free}$ of the prisms taken from the background and the flat prisms and the initial moisture content h_m on the removal after 2 to 3 days' contact with the background. The test results could be very well described with the selected potency approach in general.
- The general purpose render tested is just as favourable to the occurrence of damaging cracks on the backgrounds tested as the lightweight render and the ultra-lightweight render, as the renders possess approximately the same mechanical properties.
- With the assistance of the property values compiled in the databank a relationship was derived between the tensile and compressive strength of general purpose render and lightweight render on the background, which permits the tensile strength of a render to be estimated from the compressive strength which is easy to determine.
- For the evaluation of the crack safety or the risk of damaging cracks, with the criteria developed (Equations (4) and (5)) the following procedure results:

  (1) Estimate of the risk of cracks with the K_R-value (Equation (4)) and the mechanical and physical properties of render on the background. For an appropriate estimate R had to determined with tests. Situated on the safe side R = 1 (complete prevention) can also be adopted. Here the following

  $K_R < 1$: increased risk of cracking ⇒ Evaluation of the damaging Effect of the cracks with Equ. (5)

  $K_R \geq 1$: very little or no risk of cracking ⇒ no further evaluation necessary

  (2) Evaluation of the damaging effect of possible cracks with Equation (5) and the mechanical properties of render and background and also render and thickness of shells resp. effective thickness.

5 LITERATURE

/1/ Schubert, P.: Putz auf Leichtmauerwerk, Eigenschaften von Putzmörteln. Berlin: Ernst & Sohn. - In: Mauerwerk-Kalender 18 (1993), S. 657-666

/2/ Schubert, P. ; Beer, I. ; Graubohm, M.: Risssicherer Außenputz auf Leichtmauerwerk. Aachen : Institut für Bauforschung, 2004. - Forschungsbericht Nr. F 861