CONTENTS AND STRUCTURE

This paper first of all outlines, in chapter 2, the special properties of gypsum-based masonry that have to be accounted for in connection with refurbishment projects. Among these features are a very distinct deformation behaviour, the dependence of the mechanical gypsum properties on the moisture level, the gypsum solubility, and its incompatibility with hydraulic binders. The extreme durability of historic gypsum has to be attributed to the special methods that were used for producing these historic construction materials. Even today, a fairly large number of historic buildings with gypsum-based mortar can still be found.

After giving a brief overview of the rheological models for viscoelastic material behaviour in chapter 3, the paper goes on to explain the fundamental relationships between stress, strain and time under single-stage load conditions. The creep theories that start on this basis, with stress history variations "creep with age", "delayed elastic creep", the product model and the summation model, and how the rheological models are applied to these theories are discussed. Since creep is often the only criterion that is used for determining viscoelastic behaviour, the most commonly used models are presented with which conclusions about relaxation can be made from the creep behaviour. The paper finally deals with special aspects of load-specific dimensional change of gypsum and gypsum mortar. Causes of plastic deformation and the influence of source materials, apparent density and load are also discussed. In this connection, too, the moisture dependence of the creep behaviour of gypsum is given special attention. Available models for describing the creep behaviour of gypsum are presented.

In chapter 4, different aspects of the durability of historic masonry are discussed, and the fact that thermal and hygric strain that results from atmospheric stress conditions induces constraint stress in the masonry is addressed. In particular in the jointing mortar and in the mortar-and-stone bond, this constraint stress can cause cracks. But mortar weathering and efflorescence can also damage the jointing mortar. Various requirements have been formulated in the past for mortar properties on the basis of the described stress and damage mechanisms. These requirements are compiled and analysed. Since damage mechanisms that have an effect on durability normally have to be attributed to the moisture and heat budget in the masonry, the paper gives a brief overview of the moisture and heat storage and transport mechanisms in porous construction materials. The last section of this chapter provides an overview of models that are available for assessing the durability of masonry, which are then analysed with a view to the viscoelastic material behaviour and the moisture dependence of mechanical properties, and subjected to a concluding assessment. In addition to empirical models, the paper also describes simple engineering models for calculating stresses on the masonry surface or in the mortar-and-stone bond, as well as more complex FE models. The latter generally combine moisture and heat transport calculations with subsequent structural analyses.

A central element of this paper is an extensive research programme about the creep behaviour of gypsum and gypsum mortar, which is described in chapter 5. Before developing and explaining the test programme with compression and tension creep tests, the mortars and raw materials are characterised. After that, the test set-up is described and the tests results are presented and discussed. Next to the loading level, the material moisture is a major factor that has an influence on the creep behaviour. There is an evident similarity between all creep graphs and the solution of the differential equation of the BURGERS model. In conclusion, the results of further investigations into the physical and mechanical properties of mortar are presented.

In chapter 6, the results produced in the creep tests are entered in a moisture-dependent creep model. The moisture development in the specimens as a function of time is determined with an FE programme (DELPHIN). The moisture storage functions that are necessary for these calculations are approximated. In a next step, the paper demonstrates that owing to the moisture-dependent formulation of the dampers in the BURGERS model, the deformation in the load region can be fairly well adjusted to the deformation behaviour of the gypsum mortar. However, the spontaneous elastic recovery after unloading is grossly overestimated. By implementing a moisture-dependent formulation of the model parameters that are of relevance in this case, the results obtained from compression and tension creep tests can be calculated with good agreement. Unlike creep models for cement-bound mortar, the creep model is in this case only determined by the moisture content of the specimen and not the age at the time of loading.

The model developed in [4.33] provides the basis for the engineering model that is described in chapter 7. Due regard given to the hygric, thermal, elasto-plastic deformation and creep, the stress in the joint is calculated. After verification, the model is linked to a database. The engineering tool that is thus produced offers a simple way of conducting semi-quanitative parameter studies that can be used for adapting the mortar to the construction project in question. A research model has been developed for more detailed bond analyses. This model uses real climate data for calculation and considers time- and moisture-specific material properties. It has a modular structure: together with the DELPHIN programme, linked heat and moisture transport can be calculated. There is an interface for data conversion and transfer to the DIANA programme that is used for structural analyses. Results are verified with twin-stone specimens.

Findings are presented in chapter 8, which also outlines the aspects that future research for modelling the durability of historic masonry should deal with.