Summary

Many walls of historical buildings exhibit cracks through the entire thickness of the wall. Such cracks are often caused by "historic", but also by recent non-uniform settlement along the base of the wall due to non-uniform ground, ground water lowering etc. As the distribution of the loads may also vary via the inhomogeneous and partially deficient foundation, hollow or saddle settlements result. Due to settlement differences, restraint actions arise in the foundation and in the wall. These actions reflect the interaction of the wall with the foundation and ground.

CHAPTER 2 deals with the interaction between ground and foundation. At first, the basics regarding foundations of historical buildings are presented. The influence of building stiffness, ground stiffness and system stiffness of wall strips on base pressure, which leads to restraint stress in rising masonry is following. An overview regarding settlement is then given.

The values of allowable settlement differences indicated in the literature essentially are based upon observations on buildings. TERZAGHI (1935) started the discussion about settlement differences. They have to be considered for building structures (except for foundations on rock). Damage criteria were determined by observations of existing buildings. Following parameters must be known to determine the restraint stresses caused by differential settlements: the distribution of settlement below the foundation, the time dependence of settlement and the location of soil layers sensitive to settlement.

Settlement distributions exhibit different shapes. The basic form represents the settlement hollow. It appears in case of a soft building structure and a homogeneous soil layer. Since such case hardly occurs, different formation shapes will appear. The temporal process of settlement is dependent on the ground. Buildings on sand or gravel layers already reach their maximum settlement after few months. On the other hand, foundations on cohesive soil reach their maximum settlement only after long periods or a continuing creep can be recognised. Settlements can also occur unexpectedly. Sinks, mining industry activities etc. may lead to sudden settlement of buildings.

Boundary values for settlement differences can be defined by the angle, by the curvature and by the absolute values of the maximum settlement. Damage boundaries achieved by different authors are analysed. They are summarised in Table 2.8. Within the framework of the present work, settlement measurements were conducted on nine churches in the south east of lower Saxony. While seven of those building were characterised by considerable cracks, Two of them were uncracked. Settlement curves were recorded. The results were compared with the boundary values by SKEMPTON ET AL. Those values have been confirmed. Thus future settlements due to modification of the ground-water level and of the load etc may be predicted. However, the determination of the load bearing capacity of natural stone masonry under bending restraint is still lacking.

Therefore, the fundamentals regarding load bearing capacity of natural stone masonry are shown in CHAPTER 3. Structure and bonding of masonry are described. In the next step, a description of the mechanical properties of historic mortars and natural stones is presented, which is diverting in material properties of masonry. The state-of-the-art regarding load bearing capacity of masonry under uniaxial and multiaxial compression and tension is following.

To analyse the deformation and fracture behaviour of single- and multi-layer walls, experiments have been conducted. CHAPTER 4 deals with the own experimental work. First, the test program including masonry bond and the material properties of the stone material are described. The laboratory test set-up constructed for the purpose of masonry test follows. A hollow with a uniform curvature was forced on the wall strips. The deformation, cracking and fracture behaviour were examined. Deformation measurement occurred as well by means of LVDT and by photogrammetry using 300 targets to measure the in-plane and out-of-plane deformation vectors. The walls were prestressed across their front sides while retaining the current bending conditions. The bending load was increased up to maximum load capacity after prestress was set up totally. In addition to laboratory testing, a wall section of the Hedeper church was examined in situ.

Bending cracks were essentially observed in the masonry throughout the experiments. A mechanical model for natural stone masonry is suggested in CHAPTER 5 based upon the mechanical properties determined from the experiments. The masonry and the foundation are represented by an analytical load bearing model for a two-layer system. Taking the material properties of the materials used, it could be shown, that the masonry bond has a significant influence on the tensile ultimate strain. By prestressing the wall strip in its lower part, the initial load bearing stiffness bending strength of masonry can be restored. Crucial deformations leading to cracks in the wall strip are determined by means of the implemented mechanical model. For the cracked state, the moment-curvature-line of the two layers system can be determined by means of a finite strip-method. The system wall strip and foundation is subdivided into 800 layers of equal thickness. For each numerical loading step, the equilibrium strain distribution is determined by an incremental procedure. It is furthermore examined, which surcharge is required in order to achieve fracture momentum in the system and which load can still be bearded within the cracked system. A description of the load bearing capacity after prestressing of the wall strip is also given.

CHAPTER 6 deals with recommendations regarding practical implementation of restraint and cracking of natural stone wall due to settlement.