A new guideline for the planning and reconstruction of mortar joints and grouting of natural stone masonry, strategies for enhenced durability

Objective and State of the Art

All over Germany many premises, e.g. ancient buildings, bridges, pillars reveal decaying mortar joints on stone masonry. Especially the surfaces of the joints are brittle and weathered. The damage is caused by different forms of physical or chemical attack: natural ageing, weather attack or abrasion. Many cases are also triggered by inappropriate mortar recipes, wrong materials or even non-professional completion..
Within this project only the first 5 centimeters of the grouts in joints were investigated. The so-called coverage of joints is regarded as decisive or the key to the durability of masonry.

Aim of the Research Program

Exposed masonry can not only be judged by the look. It may be constructed by different masonry types - in the sense of structural mechanics - beneath the surface. Often it is threatened by rising damp, old grouting with damaged materials, damaged roofing or salt input by freeze-thaw salts, fertilizers, feces, cements or the solubility within the construction itself. This has to be regarded while planning reconstruction.
The research program showed that the first step for surface-grouting is to regard all these former threats, as well as the nomination of aims for necessary improvement. For the selection of mortar mixtures, the following impacts and burdens have to be considered:

- Thermal strains and stresses lead to volumetric strains. If the mortars in joints are missing, the stones can expand unhindered and the joints are decreasing in width. In the case of mortar-filled joints there is an interference of stone-mortar expansion and the expansion of the grouting itself. Such stresses may lead to strains and damages may occur. Those damages may affect the stones and the mortars.
- Overloading by hygric swelling and too heavy working loads could also lead to similar destructions, like mentioned above.
- The stone brick and masonry dimensions and the width of joints are also influencing the degree of deformations. They have to be calculated for the selection of the mortar.
- Natural weathering and the impact of pollution might change the properties of the masonry additionally. New technical properties can also be used for the tailoring of the mortar.
- A common influence is salt burst by freeze-and-thaw salts for weakening the former joints.

The research project proved, that all factors mentioned above, led to different stresses and strains in the joints. They were estimated by magnitude to influence each other by way of interdependency. Especially in the case of decreasing joint width by stone swelling, this can lead to large compressive stresses in the mortar. Stones with high water absorption are due to swelling which decreases the width of the joints. The velocity of capillary water uptake leads to the swelling time, the real deformations are even more complex. By use of simulation tools, measurements on monuments, test walls and mortar samples deformation models for the processes could be gained and later on simulated. The results showed that as a second step even more data had to be acquired to arrive at realistic models.

For the selection and mixtures for grouts a guideline has been developed. On each step the user has to decide on his own approach. Different alternative solutions are offered. The single steps are:

- Description of the reason and the aim of the grouting
- Information available of the building in need of restoration
- Data summary and evaluation of the existing information
- Technical requirements for the grouting
- Market analysis for appropriate mortar
- When needed: development of new mortar
- Testing fields
- Standard operation procedure for the grouting
- Grouting of joints
- Inspection or monitoring of the grouting process
- Inspection or monitoring after the grouting, quality of performance
- Inspection or monitoring after a couple of years (durability)

Conclusions

The aim was to tie together all the information concerning building data, building conditions, material properties, influences by use and exposition or pollution and use them to conclude appropriate material combinations for mortar within joints. The technical properties of the mortar are highly variable and can be adopted to the technical requirements and the desires of the building authorities. This is a guideline for owners, building authorities, construction companies and planning offices, for the use from planning to the progress of work. By using the steps of the scheme a person can determine a restoration aim and plan all the steps required: mortar selection, jointing to monitoring at the end.

Research Funding

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Appendix of Figures:

Fig 1: Jarmen.tif
Fig 1: The local Church in Jarmen (Vorderpommern/Germany). Grouting with mortar that contains calcareous shell fragments.

Fig 2: Worms.tif
Fig 2: Part of the masonry (outside, facade) of Worms Cathedral.

Fig 3: Wart_Pfeiler.tif
Fig 3: Wartburg Castle at Eisenach, buttress of the defense wall, south-west side after reconstruction and restoration.

Fig 4: Wart_Wehr.tif
Fig 4: Wartburg Castle – south part of the defense wall after reconstruction.

Fig 5: Kalksteinmauer.tif
Fig 5: Part of an isolated limestone wall in Niedergrunstedt close to Weimar/Thuringia showing new grouting (left side) and old mortar (right side).

Fig 6: Mansfeld.tif
Fig 6: Mansfeld Castle – freshly restored part of the wall of the castle ruin Mittelort.

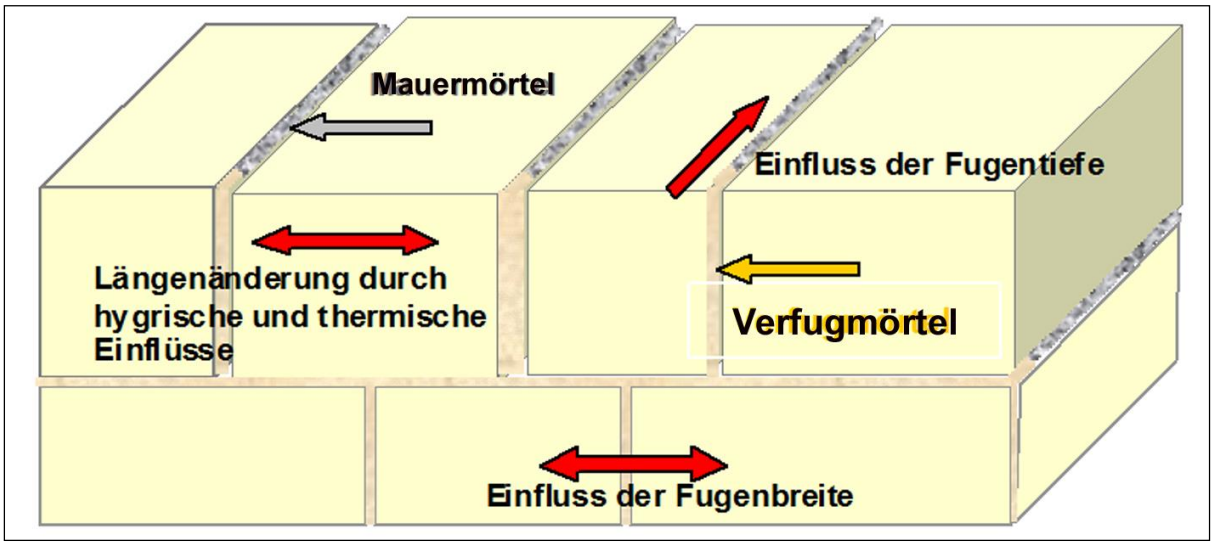

Fig 7: Schema.tif
Fig 7: Schematic draft of all the influences on masonry on joints and bricks and inter-dependencies.