Zukunft Bau

SHORT REPORT

Title

Entwicklung von Bemessungshilfen für die Tragsicherheitsbewertung von Gewölbekonstruktionen im Hochbau
Development of a Dimensioning Assistance for Vaults for Building Constructions

Motivation

The computation of vault structures is often associated with very high uncertainties. By means of the current available calculation methods, different load bearing reserves are unconsidered, wherefore the structural safety can‘t be verified. By the application of the plasticity theory and the consideration of the backfill at the resistance site, essential load bearing reserves can be developed.

Description of the Research Project

In these days backfills of vaults are mostly considered at the influence site. The enhanced effective cross section, which leads to a stiffness effect and a higher load bearing behavior, is normally disregarded. The aim of the research project was to develop a mechanical model which is easy to use and which considers backfills of vaults at the resistance site for the computation of load bearing behavior. The focus was on flat vaults which represent most of the vaults in building constructions. These in the past disregarded load bearing reserves were determined qualitative and quantitative with the help of laboratory tests and attendant numerical calculations. In the laboratory tests the vaults were monitored by use of a 2D-fotogrammetry to evaluate minimal developments of cracks and to conclude of the depth of the gap in bed joints.

A load impacting on a vault leads to an altered bending load in the vault masonry and therefore to an additional curvature of the longitudinal vault axis. Assuming a stiff shear joint between masonry and backfill, this additional curvature will also induce a force on the soil. If the shearing strength is not exceeded, stresses in the backfill will occur depending on the modulus of elasticity which can be ascribed to a bending load with overlaid longitudinal pressure loads. It must be taken into account though that the vault masonry as well as the soil exhibit a very low tensile strength. The cross-section parts that can be attached for the load transfer should therefore only have compressive stresses. This in turn means that the remaining cross-section parts should be disregarded for stress analysis.

Under simplifying assumptions, a mathematical relationship can be derived for a specific cross section along the longitudinal axis of the vault, in which the participating cross section parts of the vault masonry and backfill can be calculated in advance of a stress calculation. The contributed cross section parts in the considered cross section of the vault are dependent on the ratio of moduli of elasticity of the masonry and the backfill, the calculated eccentricity of the normal force in the vault masonry without taking into account the contributing effect of the backfill and the available cross-sectional heights of the two partial cross sections. This mathematical relationship was formulated for the first time in line with this research project. The results were verified on a large-scale test series of masonry vaults as well as on experimental numerical models.

For the separation of the influence of the backfill, a test series with four different types of vault constructions was chosen:

Test 1: Vault without backfill as reference for the load bearing capacity and the load deformation behavior without backfill
Test 2: Vault with backfill, the load acting directly on the arch construction and passing through the backfill
Test 3: Vault with backfill and load at the height of the "ground level"
Test 4: like Test 3, but with a sliding layer between masonry and soil to get findings of the influence of thrust transmission

The load-induced curvature of the longitudinal vault axis leads hypothetically to additional stresses in the backfill, which are directed tangentially to the longitudinal vault axis and which are the prerequisite for the fact that the backfill participates in the load transfer according to the established hypothesis. Regarding to the test-based proof, therefore it was important to measure these load-induced stress fractions in the backfill, directed tangentially to the longitudinal axis of the vault. The separation of these stress fractions could be successfully carried out with a soil pressure measuring panel, which was developed for the vaulting tests. Theses measured stress fractions could be compared with the results of the numerical calculations as well as the simplified mechanical model.

For the numerical modeling, a discrete approach was used for the vault masonry. The modeling of the backfill was carried out as a continuum, whereby both a linear-elastic approach as well as a Drucker-Prager approach was investigated.

Conclusion

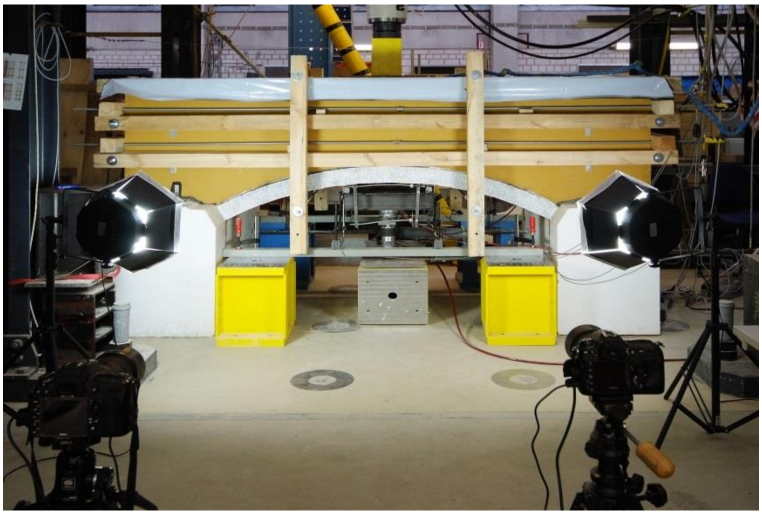
A contributory effect of the backfill has been proven both model-based and from the results of the experiments. However, in the quantitative assessment the stresses in the vault masonry were underestimated by using the simplified mechanical model. Especially the assumption that the cross section of the backfill remains flat could be a reason. If there is the aim to use simplified bar-shaped models for computing stresses in line of the calculation of arched and vaulted structures in the future, this should be done taking into account the horizontal compliance of the support points as well as of the backfill. However, considering the backfill, the model error must be taken into account by reducing the stiffening modulus of the backfill.

Basic Data

Topic: dimensioning assistance for vaults
Researcher / project management: Jens Piehler, M.Sc.; Univ.-Prof. Dr.-Ing. Steffen Marx
Budget: 124.710,00 €
Funding: 61.250,00 €
Duration of the project: 18 months

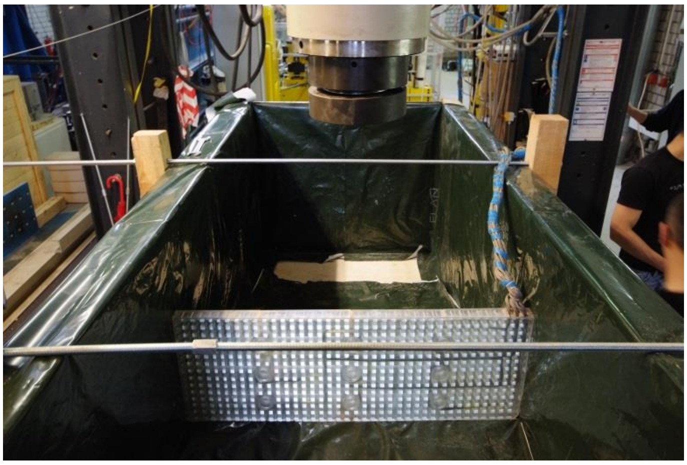
BILDER / ABBILDUNGEN:

Fig. 1: 1_Versuchsaufbau_Ansicht.jpg



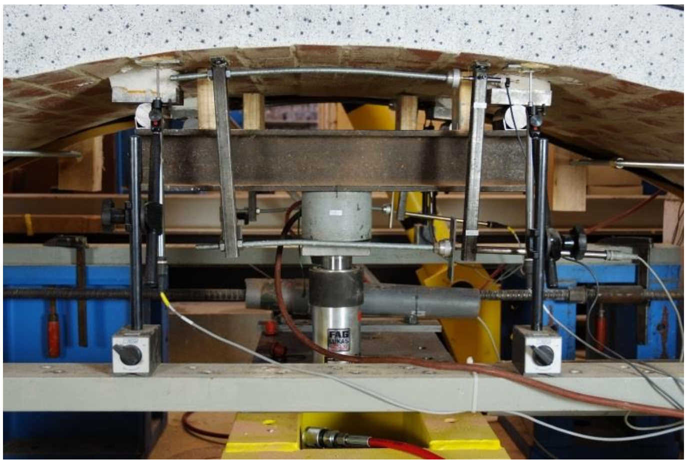
Side view of the testing vault

Fig. 2: 2_Erddruckmesspanel.jpg



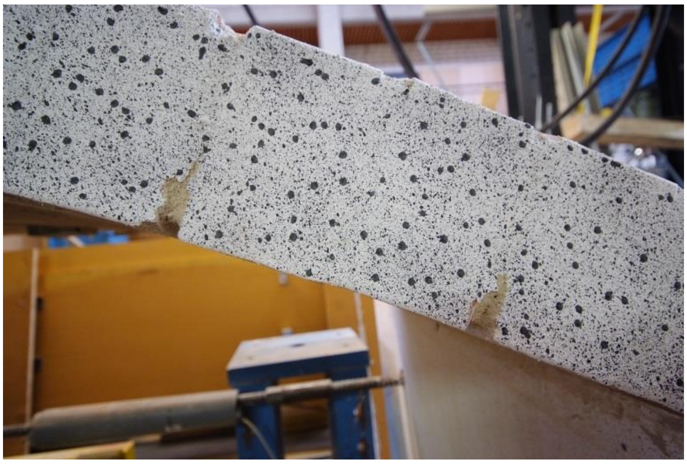
Sensor panel for the measurement of horizontal soil pressures at the top of the vault and foil wrapping for the minimization of friction between the filling material and the boundary box

Fig. 3: 3_Unterstuetzungskonstruktion_Gewoelbe.jpg



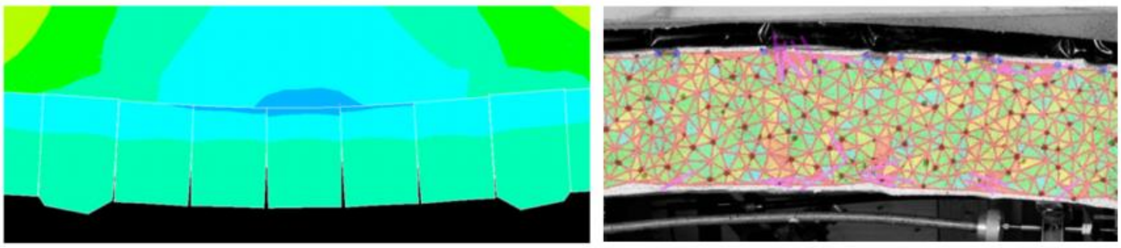
Temporary vault support construction and setup for curvature measurement

Fig. 4: 4_Versagen_Intrados.jpg



Failure pattern of the vault at the one-third-way position

Fig. 5: 5_Vergleich_FE_Fotogrammetrie.png



Comparison of the open gap at the top of the vault at a testing load of 64 kN; left: FE simulation, right: results of the 2D photogrammetry during the Test 3