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STRUCTURAL BEHAVIOUR OF BRICK LINTELS WITH UNGROUTED PERPEND JOINTS IN THE MASONRY ABOVE

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ABSTRACT

The German standards do not take into account that on-site most of the vertical joints within the masonry situated above brick lintels are left unfilled with mortar for economical and technical reasons. The paper describes a realistic model of the structural system while taking into consideration the interaction of a bracing element on the top, the lintel and the masonry bricks with ungrouted perpend joints.

Key words: *Brick lintel, perpend joints, bracing, structural behaviour, bar structure system, parametric study.*

2. INTRODUCTION

Brick lintels represent flexural and shear stressed structural members obtaining their load-bearing capacity while interacting with the compression zone resulting from the masonry situated above. In order to transfer compressive forces it is necessary to equip the masonry situated above the brick lintels with stabilized horizontal and vertical joints. This requirement is fixed in the two standards for supervision of constructions DIN 1053-3 (1) and DAfStb-Flachsturzrichtlinie (2) for dimension of lintels.

In practice however, masonry situated above the lintel zone is principally realized by ungrouted perpend joints and tongue and groove system for physical and economical reasons. However, this construction of the lintel masonry differing from the standards did until now not cause great damage; therefore it is to assume that, herewith, different supporting members are enforced resulting in a load-bearing capacity which is similar to a construction of the lintel masonry with processing of vertical joints. These supporting members and the resulting structural system are described in the following. The capacity for brick lintels with masonry above without processing of vertical joints will be presented within a parametric study.

3. SUPPORTING MEMBERS OF BRICK LINTELS WITH MASONRY ABOVE WITH UNGROUTED PERPEND JOINTS

3.1. Brick lintel

The brick lintel does not take any longer the bearing function of the tie member because the strut and tie model according to Ohler (3) is no longer applicable as a result of the missing force induced compressive contact within the compressive zone. It can rather be considered as an independent supporting member in form of an elastically restrained flexure beam by a vertical load in the support zone. As a consequence, the brick lintel has to absorb within the ultimate limit state the bending moment and the moment at support respectively in the midspan as well as in the support zone as a result of dead weight of the lintel and of the wall construction of the masonry above until bracing. In addition to the flexural design a proof of shear force according to DIN 1045, 17.5.5 (5) (4) has to be delivered as well.

In case of serviceability limit state it is necessary to prove the deflection control according to DIN 1045, section 17.7. 1/500 of the span has to be assumed as standard value for the deflection control according to ISO 4356 (5). The calculation of the deformation of the brick lintel is realized according to the method of EC 2, part 1, appendix 4 (6). In order to record the drop of the flexural stiffness under load until a deflection in the midspan of $l_s/500$, deflection tests under short-term loading have been realized on brick lintels with cross-sectional dimensions b/d = 17.5/7.1cm. Resulting from the test analysis the reduced flexural stiff-

ness $EI(f_{centre} = l_s/500)$ of the brick lintel is determined with the help of regression calculation depending on the span l_s, on the modulus of elasticity of the sealing concrete E_c and on the final value of creep coefficient of the concrete $\varphi_{c,\infty}$

$$EI(f_{centre}=l_s/500;\ l_s;\ E_c;\ \varphi_{c,\infty})=(0{,}1505 \cdot l_s+0{,}3202) \cdot E_c/(1+\varphi_{c,\infty}) \cdot I_I \qquad (1)$$

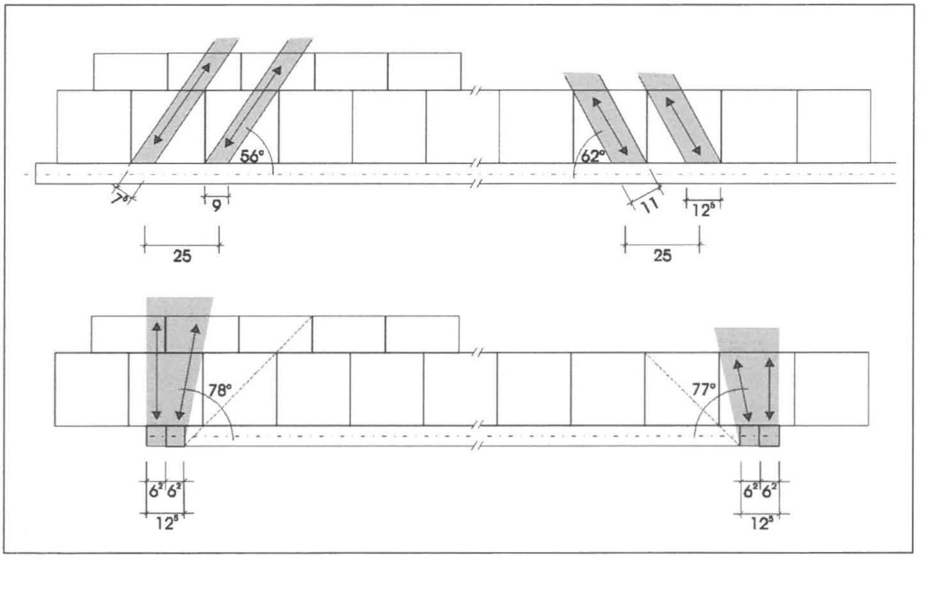
3.2. Masonry above with ungrouted perpend joints

Because of ungrouted perpend joints it is not necessary to assume a transmission of compressive force and, subsequently, a strut formation between the bricks during construction of the masonry above the brick lintel.

The bricks above the lintel opening therefore only can contribute to the total load bearing performance of the lintel construction via a diagonal strut whose inclination is developing according to the wall brick's geometry. The strut there can be formed for each single brick between the vertical joints and between the bracing and the brick lintel (see Fig. 1). Because of the considerably lower flexural stiffness of the brick lintel in relation to the bracing and the therefore resulting higher deflection of the brick lintel under load, the strut, however, only can be activated in the zone nearby the support and in case of steep inclination.

In the zone of the support the vertical and horizontal internal forces of the bracing are transferred to the masonry above and from there to the brick lintel and in the further course to the wall (see Fig. 1) with the help of struts which are arranged in a fan-shaped layout. The fan-shaped layout induces the development

Figure 1. Inclined strut formation in case of single-layer or double-ply masonry situated above the lintel.



of struts presenting different inclinations. For the vertical struts it is necessary to deliver proof of compressive stress according to DIN 1053-1 (7), for the inclined struts proof of compressive stress and shear analysis according to DIN 1053-1 has to be established. The lowest and in view of the proofs therefore most unfavourable cross-sectional geometry of the struts arranged in a fan-shaped layout exists at the bottom of the masonry above. It depends on the support's width and depth of the brick lintel which, as a rule, amounts to 12.5 cm. Consequently, fan-shaped arrangement of the struts is designed by 12.5 single compression bars of a width and a wall's thickness of 1.0 cm each in an exactly geometric way. Areas of single compression bars have to be fixed for stress analysis (see Fig. 2).

3.3. Bracing

Tie members and ring beams prefabricated from U-shaped shells or reinforced concrete solid sections as well as massive ceiling strip represent bracing systems which are important for the total load bearing performance of brick lintels with ungrouted perpend joints in the masonry above.

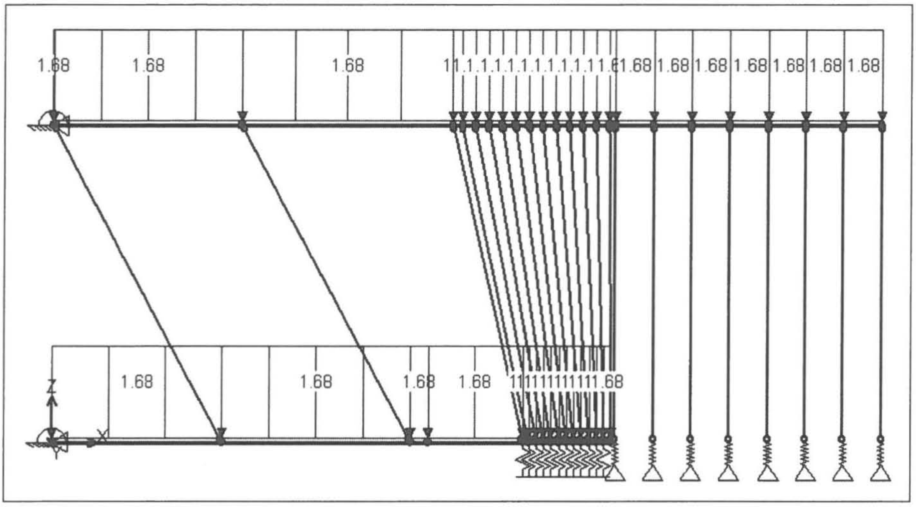
With the exception of window openings above wall angles and in case of special building units (e.g. oriel windows) the bracings proceed normally along the wall panel beyond the lintel's opening. This continuation as well as the support of the bracing on the wall panel at the side of the opening allow a restraining effect of the bracing in the zone of the lintel opening. This restraining effect is achieved during designing of the lintel system by continuation of the bracing up to about 50 cm behind the lintel opening and by creating a constant uniformly distributed load over the total length of the construction. In addition, the wall panel is presented at the side of the masonry situated above the lintel as uniform support of the bracing with the help of vertical compression bars. Transmission of the load of the bracing is realized by the structural behaviour of a flexure test beam as well as by a horizontal strut. Consequently, the bracing may be considered as partial substitution for the initially developing strut in the masonry above in case of the strut and tie model.

3.4. Interaction of different supporting members

The load resulting from the bracing is transferred over the fan-shaped struts of the masonry above into the support zone of the brick lintel. Herewith the already mentioned elastic restraint of the brick lintel is activated and, as a consequence, the bending moment and the deflection of the brick lintel under load of the masonry above is minimized. The degree of the lintel's restraint there is influenced by the inclination of the struts arranged in fan-shaped layout and by the flexural stiffness of the bracing.

There is no direct interaction of bracing and brick lintel upon a correlating deflection as a result of an external load having an effect on the bracing to expect

Figure 2. Design of supporting members in order to form a bar structure system.



as the flexural stiffness of the brick lintel is considerably lower than this one of the bracing; therefore the deflection of the brick lintel under load of the masonry above will be higher than this one of the bracing.

Fig. 2 describes the coherent design of the different supporting members building a bar structure system. Because of the symmetrical features of the construction the bar structure system is only designed until the centre line.

4. PARAMETRIC STUDY FOR THE DESCRIBED ABOVE MENTIONED BUILDING STRUCTURE MODEL

In order to assess the capacity of the building structure model the maximally resisting load q is determined for four wall constructions (Table 1) in relation to the clear distance l_w and compared to the permissible load according to DAfStb-Flachsturzrichtlinie (2). The proofs for each supporting member are realized according to chapter 3 in connection with the design standards DIN 1045 (4), EC 2 (6) and DIN 1053-1 (7).

Table 1. Survey of investigated parameters.

Wall thickness (cm)	Kind of brick	Kind of mortar	Number of layers of the masonry above	Reinforced concreted beams as bracing on the top	
17.5	HLz 8 - 0.9	MG IIa	1	9.0/19.0	17.5/25.0
17.5	HLz 8 - 0.9	MG IIa	2	–	17.5/25.0
36.5	HLz 6 - 0.8	LM 36	1	27.0/19.0	50.0/20.0
36.5	HLz 6 - 0.8	LM 36	1.5	27.0/19.0	50.0/20.0

5. CONCLUSIONS

The capacity of the building structure model resulting from the parametric study may be assessed as follows:

- In connection with a bracing brick lintels with a height of 7.1 cm may sustain loads in the role of independent supporting members and are able to transfer it over a limited clear distance. In case of single-layer masonry above in the internal and external wall zone clear distances up to 1.25 m may be overstressed, in case of multi-layer masonry above only clear distances up to 1.00 m may be overstressed because of the load of the masonry above acting on the brick lintel.
- The criterion for the limitation of maximal span is always the deflection proof of the brick lintel because of load resulting from the masonry above; there the action of a supplemental external load is not required.
- The maximal load applicable on the bracing is determined by the shear analysis of the masonry above in the zone of the fan-shaped struts.
- The diagonal struts in the masonry above in the zone over the opening only are activated in case of an arrangement very close to the support and in case of very steep inclination of the strut.
- The building structure model of brick lintels with ungrouted perpend joints in the masonry above reveals lower capacity in case of single-layer masonry above and clear distances of 1.00 m compared to dimension according to DAfStb-Flachsturzrichtlinie. A high flexural stiffness of the bracing may achieve a better result in case of single-layer masonry above and a clear distance of 1.25 m than according to DAfStb-Flachsturzrichtlinie. In case of multi-layer masonry above the capacity of brick lintels with grouted perpend joints in the masonry above is considerably higher than this one of brick lintels with ungrouted perpend joints in the masonry situated above.

6. ACKNOWLEDGEMENTS

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