Application and design of wood stave pipelines

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Summary

The objective of this paper is to present a design method for wood stave pipelines. Based on comprehensive experimental and numerical studies dimensioning span tables were derived for the design of wood stave pipelines on bearings. Additionally the influence of moisture content on basic properties of different wood species was analysed.

1 Introduction

In the context of a research project studies for the application of wood stave pipelines as inlet pipe for hydroelectric power stations were performed. The wood stave pipelines shall be used in mattock caves in Java, Indonesia in order to use underground water resources for the local population (Fig. 1). The access to the caves is very cramped; therefore pipelines of steel or concrete can not be transported in the caves. By contrast single wood staves may be transported separately into the caves and put together to a pipeline in situ. Because of the low dead weight of the single wood staves and the adaptation to the cave gradient, wood is an adequate building material for pipelines in caves.

Fig. 1: Mattock cave in Java, Indonesia

Wood stave pipelines consist of single planks or square-sawn timber, which are put against each other and hold together with steel rings. The single wood staves have a tongue and groove joint both on the longitudinal side and at the end grain. The impermeability of the wood stave pipeline is ensured by wood swelling.

Fig. 2: Wood stave pipeline (a) in a ditch and (b) on bearings (Zwick GmbH, Canbar Inc.)

The continuous water saturation gives natural protection and reliably prevents fungal attack. The wood stave pipelines are assembled either in a ditch with subsequent filling of the ditch or, as planned in the mattock caves in Java, overground with bearings (Fig.2).

2 Experimental and numerical investigations

For the construction of wood stave pipelines two main topics were analysed:

- Influence of moisture content on basic properties of different wood species
- Load-bearing performance of wood stave pipelines on bearings

Generally mechanical properties of wood are decreasing with increasing moisture content. In experimental studies the influence of moisture content on strength and stiffness of wood was determined as well as the swelling behaviour of wood. In the context of the research project the following wood species were analysed: Akasia, Jati, Keruing, Puspa and Larch. At water saturation a maximum decrease of stiffness (modulus of elasticity E_o) up to 16 % and a maximum decrease of strength (shear strength f_v) up to 39 % were determined.

The long-time load-bearing performance of wood stave pipelines on bearings was determined using a pipeline (European Larch) with a length of 10 m and diameter of 1.4 m (Fig. 3a). The deformation of the cross-section was measured by displacement transducers, the loading of the steel rings was determined using strain gauges (Fig. 3b).

The experimental studies were used for verification of a finite element model. The finite element model was used for the determination of the complex stress condition and deformation behaviour of wood stave pipelines on bearings. A parameter study was performed by varying the diameter, the dimension of wood staves, water pressure, the distance of steel rings and the distance of bearings.

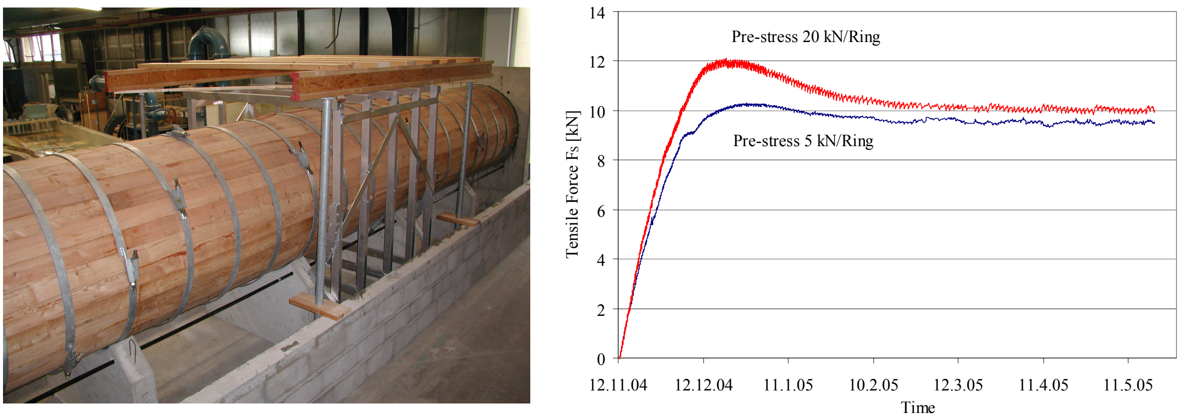

Fig. 3: (a) Experimental set-up and (b) tensile force in steel rings because of swelling

3 Design of wood stave pipelines

Based on the experimental and numerical investigations span tables were derived for the design of wood stave pipelines on bearings. The following parameters are considered in the ultimate limit states design:

Steel ring:
- Normal stress in steel ring σ_R
- Tensile force in fastening device F_S

Wood stave:
- Compression stress perpendicular to grain in circumference direction $\sigma_{c,90,U}$
- Compression stress perpendicular to grain in radial direction $\sigma_{c,90,rad}$
- Bending stress and compression stress σ (interaction)
- Shear stress τ

For ultimate limit states a partial safety factor of γ_G=1.35 for dead weight, γ_Q=1.0 for water pressure and γ_Q=1.5 for pre-stress, swelling and pressure surge was used. The span tables indicate the utilisation degree for the design parameters described above. Using the dimensioning tables, a design of wood stave pipelines on bearings (softwood: strength class C24 according to DIN 1052-2004) is easily possible. Subjected to water pressure the maximum distance of the steel rings for wood stave pipelines with diameters from 1.0 m to 3.0 m may be determined.