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Influence of Temperatures and Sizes of Work Sequence on Cracks Formation in RC Walls

Introduction

The watertight function of the underground structure of the so-called "White Tanks" have to be fulfilled not only by the foundation plate, but also by the walls. The wall shall by watertight at least 300 mm above the maximum groundwater level. The concreting procedure must be considered when designing the wall thickness, since the concrete sleeve must fit between the wall reinforcement. The recommended wall thickness is 300 mm and the maximum height should not be more than six meters or fifteen times the wall thickness, respectively (Lohmeyer, 2018). Special measures must be applied to higher walls, or horizontal working joints must be designed.

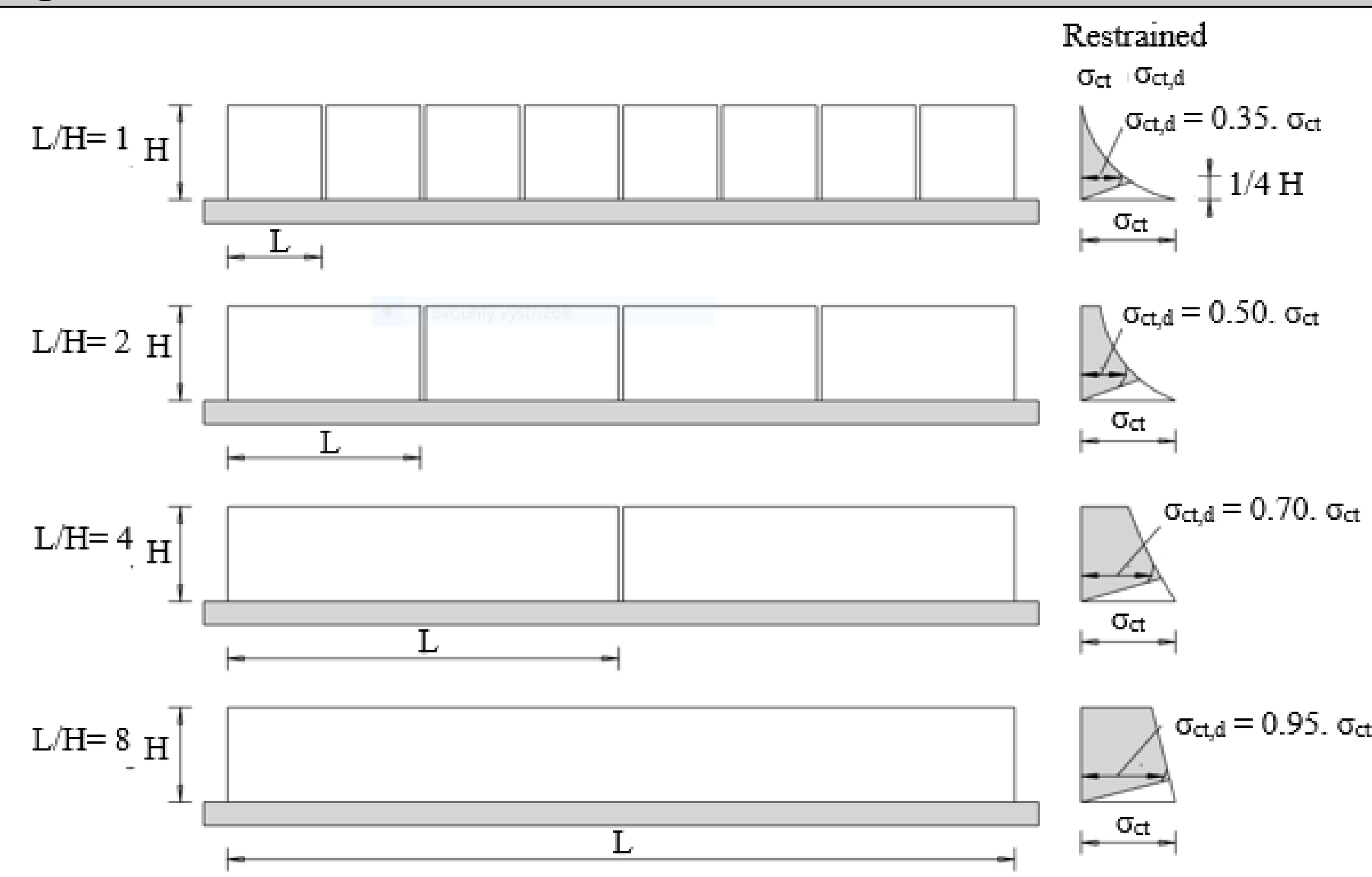
The design of the watertight concrete wall is affected by the size of the restrained stresses caused by the different time of concreting, when the hardened foundation slab prevents the wall from being free do deform at the time of hydration and subsequent cooling of the concrete wall. Restrained stresses in the walls can be eliminated by concreting the foundation slab and the wall in one work sequence, but this is not a common practice. For this reason, it is important to choose a suitable ratio of the height and the length of the concrete section of the wall, which is related to the quantity and distribution of the reinforcement and the sealing of the joints.

Crack formation and restrained stresses in the wall

The design risk of the cracking due to the control of the restrained stresses in the walls can be estimated by different methods. Separation crack in the wall occurs when the tensile stresses exceed the mean tensile strength of the concrete. By an appropriate select of the ratio of the wall length to its height, it is possible to reduce the restrained stresses in the wall cross-section. The smaller the ratio, the less the restrained stresses.

In bottom part of the wall, at the joint of the hardened foundation slab and just-concreted wall, no wide cracks can form, but only fine hairline cracks that are watertight. In the longitudinal direction of these capillary cracks, the restrained stresses of the wall develop. In the lower part of the wall (up to the 1/4 of the height) usually no reinforcement is required to control the crack width. In this area, the minimum reinforcement area according to EN 1992-1-1 clause 7.3.2 is sufficient (Lohmeyer, 2018). In the area over a 1/4 of the height it is also possible to save reinforcement, depending on the ratio of the wall length to its height. The amount of the restrained stresses depending on the selected ratio of the wall length to its height is shown in Fig. 1. (Lohmeyer, 2018)

Fig.1 The course of the restrained stresses in the wall



Example

The risk of the cracks due to restrained stresses due to the ambient temperature, the already hardened foundation slab and the ratio of the wall height to length is demonstrated in Graf. The following construction parameters were chosen for the model example:

– unchangeable parameters: concrete strength class C25/30, cement CEM III/B 32.5 R, wall height of 3 m, wall thickness of 0.3 m,
– varying parameters were the wall length from 3 m to 30 m and temperatures.

The crack formation was calculated for three temperature situations:

– summer: temperature of the young concrete of 24°C and of the foundation slab of 22°C
– winter: temperature of the young concrete of 12°C and of the foundation slab of 15°C
– spring/autumn: temperature of the young concrete of 18°C and of the foundation slab of 20°C

Other parameters were calculated based on these inputs.

Calculation of the cracking stresses

The formulas and assumptions for determining the critical time of cracking, the effective tensile strength of the concrete, as well as the cracking stress were taken from the "Weisse Wannen Einfach und Sicher literature" (Lohmeyer, 2018).

Determination of the critical time, when the first crack is expected as follows:

$$t_{crit} \approx 1.3.t_{maxT} + 24\ [h]$$

Calculating of mean concrete strength at critical time:

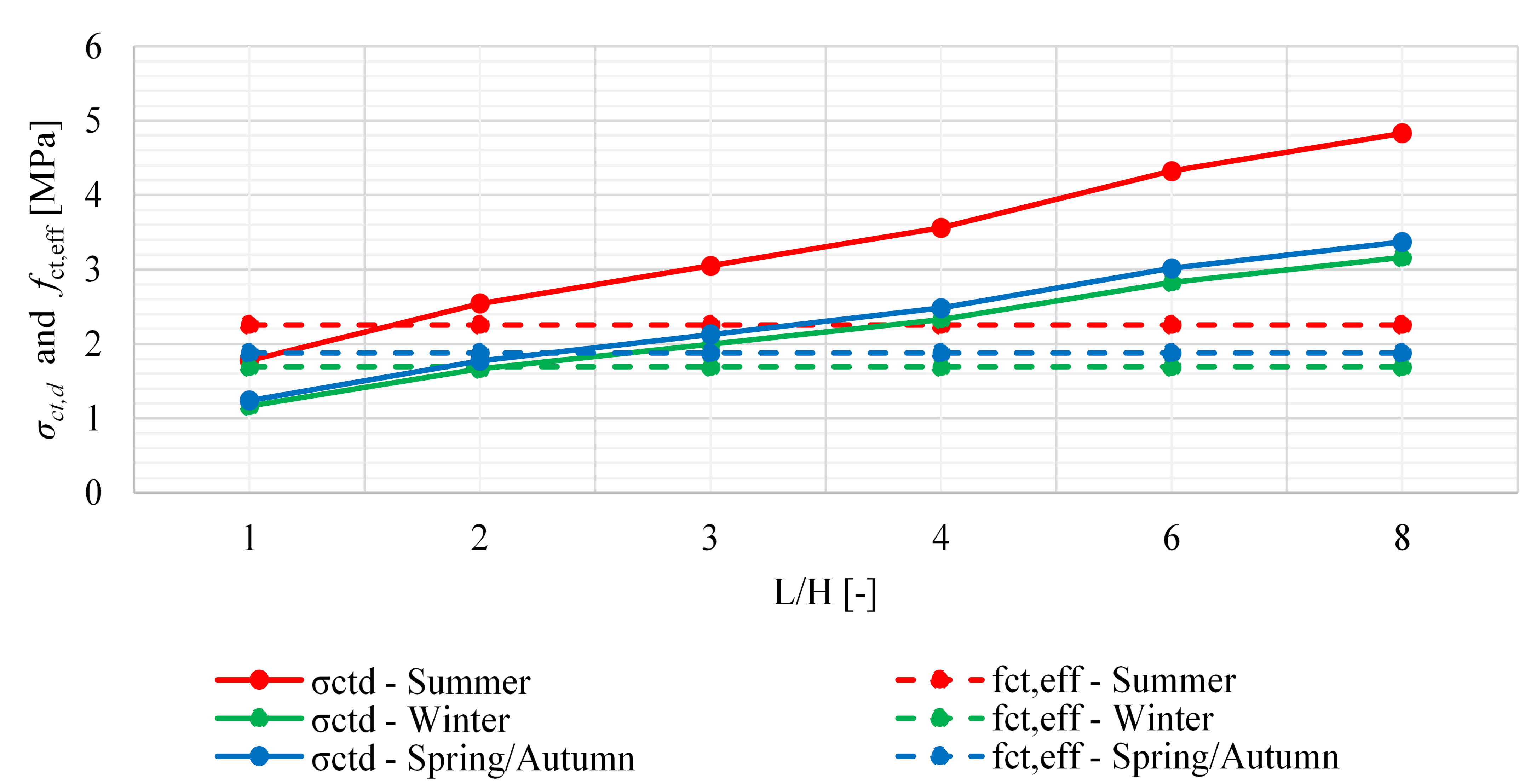
$$f_{ct,eff} = k_{ct(t)}.k_j.f_{ctm(28d)}$$

Estimation of the reduced value of the restrained stress at lower edge of the concrete wall:

$$\sigma_{ct,red} = k_{(\varphi+\psi)}.\alpha_{T(t)}.\Delta T_{B,W-F}.E_{c(t)}$$

The calculation of restrained stresses in the wall, taking into account the length and height ratio of the wall:

$$\sigma_{ct,d} = k_{ct,d}.\sigma_{ct,red}$$



References

Lohmeyer, G. and Ebeling, K. (2018) Weisse Wannen einfach und sicher: Konstruktion und Ausfüfrung wasserunduchtässiger Bauwerke aus Beton, Düsseldorf: Verlag Bau+Technik, 2018, 586 p. ISBN 978-3-7640-0623-5.

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Conclusion

Graf shows that by choosing a suitable time of concreting and the ratio of the wall length to its height, it is possible to prevent crack formation and thus save on the amount of reinforcement. The dashed line represents the actual tensile strength of the concrete at the critical time for crack formation and the continuous line represents the restrained stresses caused by the hydration of the cement and the restrain of the free deformation of the wall with hardened foundation slab. Concreting of the walls in colder weather leads to the design of a more economical structure even at lager wall length to height ratios, while concreting at high temperatures causes a high risk of cracking. Restrained stresses in summer can be up to 30 % greater than in winter, causing a significant increase in the amount of reinforcement for crack width control.



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