Design model for fatigue loadings applied to tower structures made of reinforced concrete and prestressed concrete vulnerable to vibration

During their life time, constructions for wind turbines are subjected to high cycle loadings and high numbers of load cycles. Beside maximum loads fatigue loadings could be decisive for dimensioning the construction. The fatigue verification for concrete is based on a linear damage accumulation law devised by Palmgren and Miner. The application of this simplified linear damage model could lead to unsafe or uneconomical constructions. The real highly non-linear fatigue behaviour of concrete is not considered sufficiently by a linear damage model. Effects of different orders of load cycles as well as influences due to multiaxial fatigue loading on the resulting fatigue life are not represented as well.

Based on a mechanical damage model available in literature, which was developed for uniaxial fatigue loading with constant amplitude loading, a procedure is established to determine the stiffness and damage evolution in concrete under multi-stage and multiaxial fatigue loading. Experimental testings have been performed for validating the multi-stage approach. This approach was extended by modifying material values to take into account influences of multiaxial fatigue loading,.

This extended damage approach is associated with the elastic-plastic material model for concrete provided in the FE-Program ABAQUS©. Subsequently, a numerical investigation is performed at a prestressed concrete tower for a multi-megawatt wind turbine. The results of the numerical simulation obviously indicate the influence of the order of load cycles to the fatigue life. Due to alterations of the stress distributions, a significant lower fatigue damage state occurs compared with calculation results without any stress alterations. Consequently, prestressed conrete towers can be optimised by numerical fatigue damage simulations. Furthermore, the numerical results indicate, that influences of simultaneous lateral loadings in compression or tension affect the resulting fatigue life essential.

The conclusions, obtained by the results of the numerical damage investigation, in principle are confirmed by in-situ-measurement carried out at a prestressed concrete tower for a wind turbine. The evaluation of the measured strains shows that they mainly are caused by operation of the wind turbine as well as by shrinkage and creep. Strain evolutions, which could refer to fatigue damage evolution, did not appear until now.