Lifetime prediction of textile strengthened structures

In this example, the developed neural network-based concept in [1] and [2] is applied to predict the lifetime of textile-reinforced concrete (TRC) under long-term tension load. This novel building material is developed to retrofit and strengthen aged or damaged reinforced concrete structures. Due to the early stage of development, the mechanical and physical insight into the long-term material behaviour is not yet sufficient to derive lifetime prediction models. Experimental data are only available for some selected accelerating stress levels, and the samples are rather small. This represents a typical problem in civil engineering which may be solved with the aid of the developed lifetime prediction based on neural networks.

A series of experiments were performed to determine the lifetime of TRC specimens under accelerating stress, see [3]. The specimens were placed in a climate chamber during the lifetime test to ensure constant environmental conditions. The setup of the experiments is shown in Figure 1.

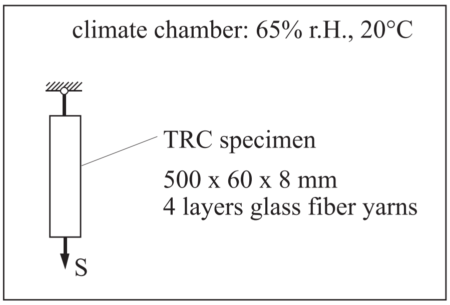

Figure 1: Setup of experiments

Firstly, the short-term tension strength $\mathrm{S}_{\mathrm{max}}$ was measured for orientation to select the accelerating stress levels properly. The accelerated lifetime tests were restricted to two test series only. The accelerating stress levels were selected in dependence on the mean value of the measured short-term strength $\mathrm{S}_{\mathrm{max}}$. In the first test series, the constant tension stress $\mathrm{S}_{\mathrm{a1}} = 0.77\,\mathrm{S}_{\mathrm{max}}$ was applied, and nine specimens were investigated. The second test series was comprised of six specimens investigated under the constant tension stress $\mathrm{S}_{\mathrm{a2}} = 0.70\,\mathrm{S}_{\mathrm{max}}$. The empirical distribution functions of the lifetime obtained from these experiments are shown in Figure 2 over a logarithm time scale.

On the basis of the scarce data from the experiments in combination with a very limited mechanical and physical insight, a traditional estimation of the acceleration function $\mathrm{a}(.)$ and, hence, a formulation of an acceleration model cannot be realised. A solution can, however, be obtained with the aid of the neural network-based concept for lifetime prediction. The experimental data are utilised for the training of the network to directly capture the features of the acceleration function. Compatible to the empirical distribution of the smaller sample, for $\mathrm{S}_{\mathrm{a2}} = 0.70\,\mathrm{S}_{\mathrm{max}}$, the probability scale is discretised with five probability levels F_{k}; see Figure 2. Then, a neural network is trained and validated according to [1] and [2]. A suitable network layout is found with three hidden layers comprised of nine, nine, and five

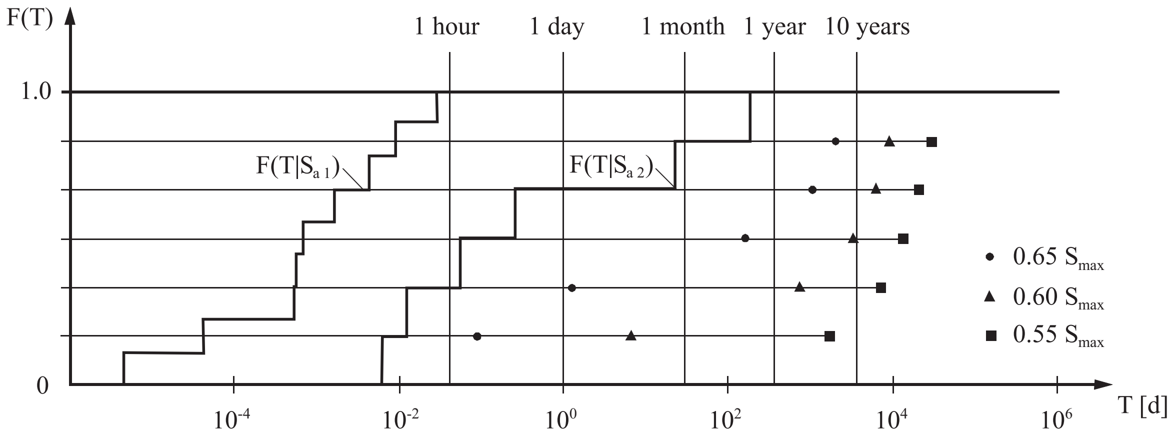

Figure 2: Empirical distributions and neural network predictions of the lifetime of TRC under constant tension stress

neurons, respectively. The prediction is realised with the averaged prediction scheme according to

$$\mathrm{T_k}|\mathrm{S_d} = \frac{1}{\mathrm{n_j}} \cdot \sum_{\mathrm{S_{ai}}=\mathrm{S_{aj}}} \left[\mathrm{a_k}\left(\mathrm{T_k}|\mathrm{S_{ai}}, \mathrm{S_d}, \mathrm{S_{ai}}\right)\right] \tag{1}$$

including both accelerating stress levels $\mathrm{S_{a1}}$ and $\mathrm{S_{a2}}$. To get some image of the lifetime of the novel material, the lifetime prediction is generated for three different levels of design stress; $\mathrm{S_{d1}} = 0.65\,\mathrm{S_{max}}$, $\mathrm{S_{d2}} = 0.60\,\mathrm{S_{max}}$, and $\mathrm{S_{d3}} = 0.55\,\mathrm{S_{max}}$. The results are illustrated in Figure 2. The mean values of the predicted lifetimes are 2, 10, and 38 years, respectively. In view of the service lifetime of civil engineering structures, this indicates that the novel material TRC may be utilized for structural retrofitting and strengthening with an exploitation of its short-term strength $\mathrm{S_{max}}$ up to $55\,\%$, approximately. Clearly, an industrial application of TRC requires extended experimental and numerical investigations to verify the predictions and to enable a structural reliability assessment. The example, however, demonstrates the practical applicability of the developed neural network-based lifetime prediction concept.

References

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