Modelling aging shotcrete: parameter identification and application

Matthias Hofmann

ALPINE BeMo Tunneling GmbH, Innsbruck, Austria

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Abstract

This contribution deals with the use of the aging concrete constitutive model of zsoil for modelling aging shotcrete. The parameters of the models are back calculated from creep tests by means of an optimization method. The use of zsoil within the framework of an optimization software will be presented.

1. Introduction

In tunnelling shotcrete is widely used as a construction material for temporary linings. Due to the early loading of young shotcrete in tunnelling a suitable material model for shotcrete should take into account aging, creep and stress dependence. The material properties of shotcrete in early ages are time dependent as a consequence of the hydration process.

This contribution deals with the use of the Z_Soil aging concrete constitutive model for modelling shotcrete in early age. For the definition of this material model many material parameters are required. Not all of them can be defined from experiments directly. That is why parameter identification is of special importance.

2. Aging concrete model of Z_Soil

The aging concrete model of Z_Soil is a visco-elastic constitutive model. It is intended to model the time dependent behaviour of concrete in early age, mainly the aging and creep behaviour. It is a rheological model and consists of a series of parallel Maxwell (spring-damper) units (see Figure 1). For a detailed description of the model see [1].

The aging concrete model requires a large number of material parameters to be defined, e.g. for three Maxwell units and 7 maturity points 24 parameters. They cannot be identified directly from experiments. In the next section an approach to identify the material parameters from creep tests by an optimization method is presented.

One drawback of the model is that the time dependence of strength cannot be simulated since that would require a visco-plastic constitutive model for example. Nevertheless it is a useful model because the aging and creep behaviour of shotcrete can be modelled well with this simple model (see section 3).

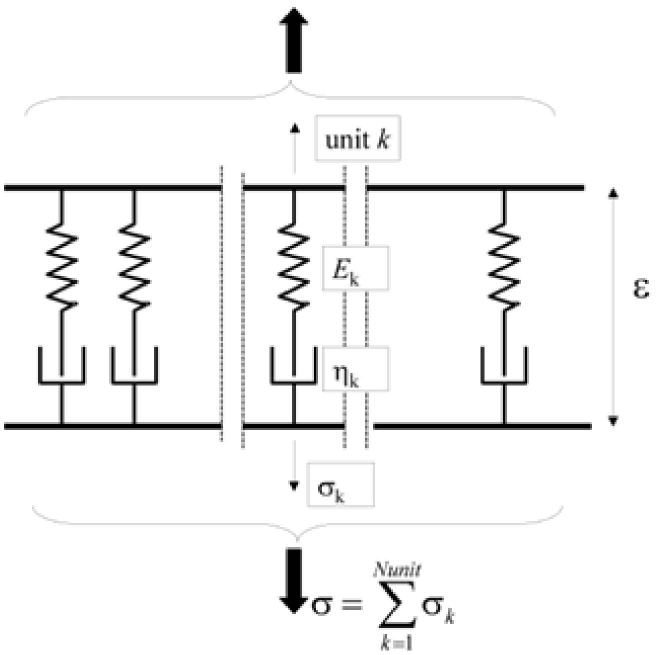

Figure 1: Maxwell chain model for aging concrete (taken from [1])

3. Parameter identification approach

Generally, deterministic models relate a set of responses $\mathbf{x} = \mathbf{x}(\mathbf{p})$ with the model parameters $\mathbf{p}$. In the parameter identification procedure the measurements $\mathbf{x}^* = [x_1^* \ldots x_m^*]$ are given from experiments. The parameters are determined by minimizing the difference between measurements and predicted model responses which results in the following objective function

$$\mathbf{J} = (\mathbf{x}^* - \mathbf{x})^T \mathbf{W}(\mathbf{x}^* - \mathbf{x}) \tag{1}$$

where $\mathbf{W}$ is the weighting matrix which is mostly assumed to be diagonal. A sketch of the parameter identification approach is shown in Figure 2.

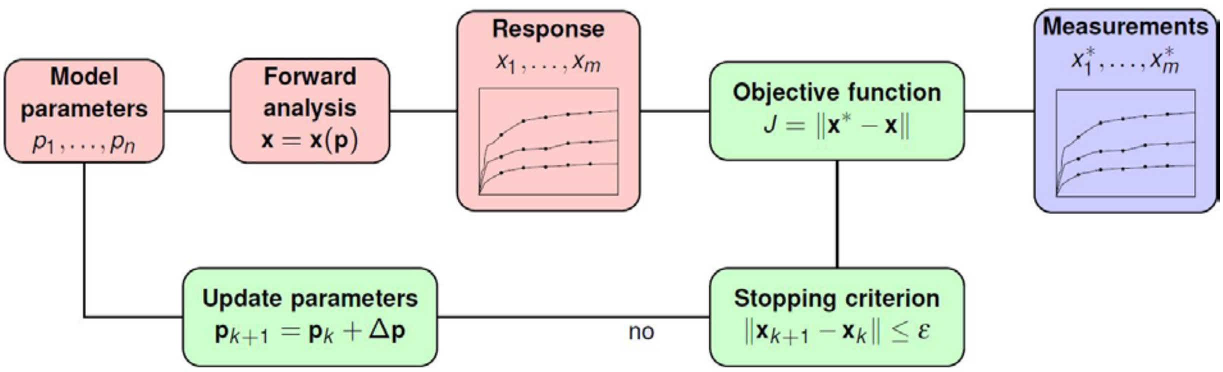

Figure 2: Sketch of the parameter identification approach

In the present study the DAKOTA-toolkit [2] was used for the solution of the optimization problem. DAKOTA offers several optimization algorithms that can be used for the parameter identification, e.g. global optimization and nonlinear least square methods. In the following examples a nonlinear least square method was used.

A similar parameter identification approach was used by [3] to identify the material parameters of the Barcelona Basic Modell [4] for unsaturated soils.

3.1 Communication between DAKOTA – Z_Soil

For the use of Z_Soil within the DAKOTA framework information has to be exchanged between DAKOTA and Z_Soil. To this end DAKOTA writes a set of material parameters to a file and calls a driver program. A python [5] script is used in the present study as the driver programm. Within this python script the current parameter set is read and inserted in a templete Z_SOIL input file. Then Z_SOIL_calc is called and the results are writen in a file for the response metrics. This file has a format that is understood by DAKOTA. Finally DAKOTA updates the parameters according to the used optimization method and another iterations starts. A sketch of this precedure is shown in Figure 3.

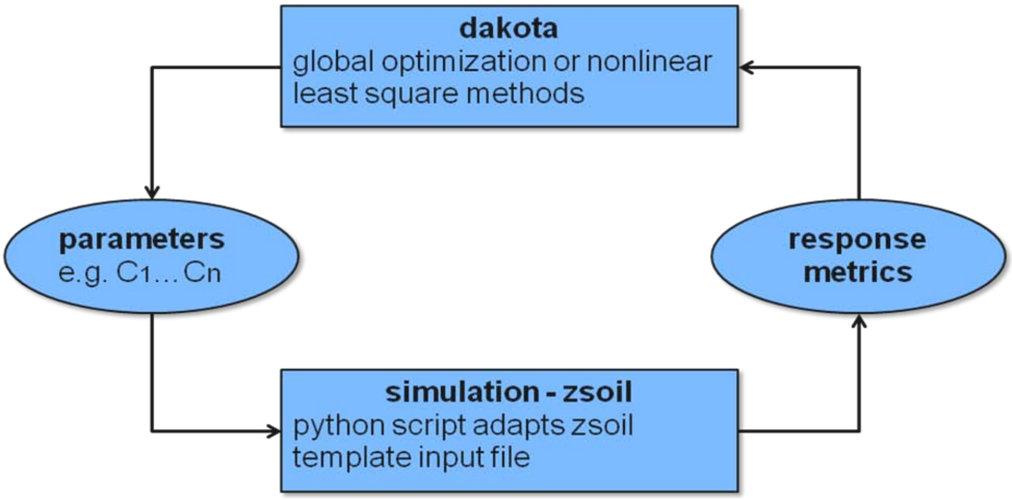

Figure 3: Sketch of the communication between DAKOTA and Z_Soil

3.2 Back calculation of creep tests

The presented parameter identification approach was use for the back calculation of creep tests. The creep test data taken from [6]. Two creep tests with constant loads of 5 and 7 MPa are used for back calculation. It has been shown that two Maxwell units for the aging concrete model were sufficient for these simple tests. Nevertheless 9 parameter have to be identified. It has to be noted that probably more tests and load changes are required to identify the parameters reliable. But the aim of this study is to show a approach for the parameter identification and therefore this two test are sufficient.

In Figure 4 the template Z_Soil model for the parameter identification of the creep tests is given. It is a simple single element model. As explained above the material parameters of the aging concrete model are adapted within the optimization process by a python script.

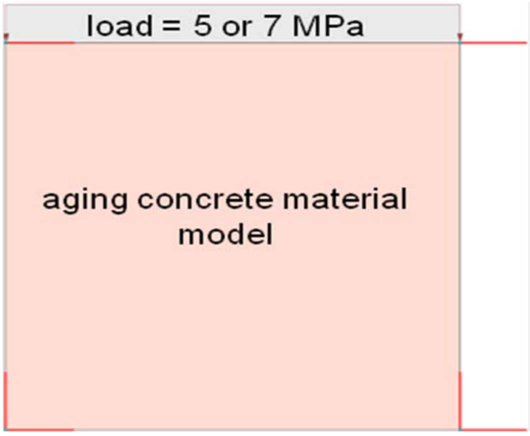

Figure 4: Z_Soil template model for the parameter identification of the creep tests

Figure 5 shows a comparison of the experimental data with the prediction of the aging concrete material model. For the diagram on the left side only the creep test with 5 MPa was used for the parameter identification whereas for the diagram on the right side both experiments were used. There is a good agreement between the experimental and numerical data and therefore the aging concrete model is able to represent the behaviour of the two experiments realistically.

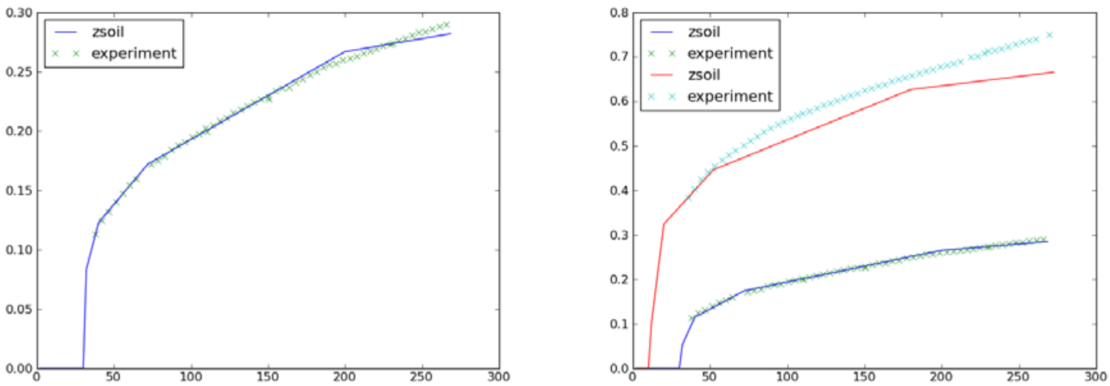

Figure 5: Parameter identification using one (5 MPa, left) and all tests (5 and 7 MPa, right)

It should be noted that the proposed parameter identification approach can be used for other constitutive models as well (see e.g. [3]). Likewise it can also be used for the identification of other parameters (e.g. loads, geometrical parameters, …).

4. Conclusion

The present study shows that the creep behaviour of shotcrete in early age can be modelled with the aging concrete model of Z_Soil realistically. The material parameters are identified from creep tests for shotcrete by means of the optimization framework DAKOTA. To this end the input and output files of Z_Soil are utilized by python scripts.

References

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