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Structural and Physical Aspects of Construction Engineering

Deflection of a Beam Considering the Creep

Jana Drienovská[a,*], Katarína Tvrdá[a]

[a]*Faculty of Civil Engineering STU, Radlinského 11, 810 05 Bratislava, Slovakia*

Abstract

This paper deals with determining the creep of a simply supported beam. Creep is a complex phenomenon configured in a different way in each program and therefore we wanted to analyze the results of the calculations in a variety of programs based on the Finite Element Method. Immediate and subsequent application of deflection function creep is examined in the ANSYS software. In ANSYS the deflection is modeled by implementing the creep curve over time. Creep analysis in this program can be in several ways. One of them is the definition of creep function by Prony series which are then used for material characteristics of the modeled structure. In modeling of a structure different types of finite elements were used. In the end, the results have been presented in tables and figures.

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Keywords: creep, Prony series; simply supported beam;

1. Introduction

In solving tasks in which deformation of material is substantially affected by time progress and by the length of the loading time interval, viscoelastic or viscoplastic constructional relations and derived material models, have been used. For the viscoelastic environment, two phenomena are characteristic: creep and relaxation. If the impulse is stress σ, the response is deformation ε, and vice versa. Under the constant load at different levels in the sufficiently long time interval, the linear progress of non-reversible deformations occurs. The rate of creep rises with higher values of load and within the complex time interval, it has been changing. The first-time interval of these curves is characterized by large deformation, and it is called the primary creep. In the second interval there is a quasi-constant rate of deformation, and the area is called the secondary creep. Under large loads, creep crack occurs, which is in the third creep. If the

* Corresponding author. Tel.: +421-2-592-74-455.
E-mail address: jana.drienovska@stuba.sk

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stress in structural elements made of viscoelastic materials reaches 50% of their calculated bearing capacity, for description of the deformation process the Boltzmann theory of hereditary viscoelasticity can be used [1, 2]:

$$\sigma = \eta \frac{d\varepsilon}{dt} = \eta\dot{\varepsilon} \quad (1)$$

Let us assume that the external effects evoke the stress level *σ(t)*. Then the deformation of a body in the time moment t will depend not only on the stress *σ(t)*, acting in the time moment t, but also on the stress *σ(t)*, which acted in the body during interval $\Delta\tau$,where $\Delta\varepsilon$ represents the contribution to resulting deformation due to the previous effects of stress.

If the deformation in time *t* is the result of progressive effect of stresses acting in previous time moments *τ*, then the deformation is a sum of deformations observed in time *t*, evoked by effects of acting stresses *σ(τ)*. Functions characterizing the rate of creep and relaxation can be obtained experimentally or, directly by deriving the functions of creep and relaxation.

Stiffness properties of material can be, due to easier solution of the non-stationary linear problem, categorized as volumetric and deviatoric ones. Deviatoric (shear) deformation properties of material are characterized by modulus of elasticity in shear *G* and the volume compressibility is characterized by the volume modulus *K*. Material properties of many viscoelastic materials under load are not constant, they have been changing in time. At certain constant temperature, they are the decreasing functions expressed e.g. in the form of Prony series:

$$G(t) = G_0^{\infty} + \sum_{i=1}^{n_g} G_i e^{-\frac{t}{t_i^G}} \quad (2)$$

Functions (2) are suitable due to easier modification by introducing the relative members α_0^G:

$$\alpha_0^G = G_0^{\infty}/G_0 \quad (3)$$

where G_0^{∞} is the sum of individual modules of elasticity in shear G_i [3].

2. Modeling of nonlinear problems using ANSYS software

2.1 Transient analysis

A transient analysis, by definition, involves loads that are a function of time. It is possible to perform a transient structural analysis (also called time-history analysis) in the mechanical application using the transient structural analysis that specifically uses the ANSYS Workbench solver. It can be used to determine the time-varying displacements, strains, stresses, and forces in a structure as it responds to any transient loads. If the inertia and damping effects are not important, a static analysis can be used instead. When performing a nonlinear analysis, one may encounter convergence difficulties due to a number of reasons. Some examples may be: initially open contact surfaces causing rigid body motion, large load increments causing non-convergence, material instabilities, or large deformations causing mesh distortion that result in element shape errors.

A material is said to be viscoelastic if consists of an elastic (recoverable) part as well as a viscous (nonrecoverable) part. Upon application of a load, the elastic deformation is instantaneous while the viscous part occurs over time.

2.2 Viscoelastic Material Curve Fitting

Viscoelastic material curve fitting determines the material constants by relating the experimental data to the Prony series expansion for both the shear and bulk modulus of the hypoviscoelastic material option. Curve fitting is performed either interactively or via batch commands. The user inputs the experimental data, defines the order of Prony series expansion, performs nonlinear regression, views the curve-fitting results graphically, compares the experimental data, and writes the fitted coefficients to the database as nonlinear data table commands for the subsequent finite elements analyses [5].