11th. World Congress on Computational Mechanics (WCCM XI)
5th. European Conference on Computational Mechanics (ECCM V)
6th. European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

CREEP BUCKLING OF VISCOELASTIC FUNCTIONALLY GRADED MEMBERS UNDER ECCENTRIC AXIAL COMPRESSION

Ehab Hamed

Centre for Infrastructure Engineering and Safety, School of Civil and Environmental Eng.
The University of New South Wales, UNSW Sydney, NSW 2052, Australia
e.hamed@unsw.edu.au

Key Words: *Buckling, Creep, Functionally Graded, Viscoelasticity*

The use of functionally graded materials (FGMs) in a broad range of engineering applications is rapidly increasing with many aspects of this concept being researched worldwide. Applications have recently been reported for sensors, armors, dental implant, rotating blades, rigid concrete pavements, sandwich panels, laminates and cement composites with variable fibers volume fraction [1-2]. Despite the large number of research studies, the viscoelastic response of functionally graded structures (FGSs) has not been fully investigated. In many cases, viscoelastic materials that creep at ambient temperatures are used in a FGS like polymers and cementitious materials; and in other cases, applications are made for structures that are exposed to high temperatures, which initiate creep in many metals and other materials. This abstract summarizes a research study that focuses on the creep buckling response of uniaxial compressed members made with viscoelastic FGMs.

The creep behaviour of uniaxial compressed members made of FGMs is associated with some unique physical phenomena that result from the gradual variation of the material volume fraction and the corresponding variation of the viscoelastic characteristics through the depth of the member. These aspects introduce significant computational challenges that need to be overcome for their analysis. Creep may cause distortions of the cross-section of the member, as well as, gradual variations of its flexural rigidities, neutral axis, and stresses distribution with time. Under axial compression loading, the deformations caused by creep along with the consequent increase or modification of the internal stresses may lead to loss of stability under a sustained load that is significantly smaller than the elastic buckling load (so called "creep buckling"). Few research studies have focused on the viscoelastic behaviour of FGSs [3] but without a detailed description of the variation of stresses and deformations in flexural members. Here, a general theoretical model and numerical tools for their viscoelastic analysis are developed, which are applicable for any FGM, different boundary conditions, and different loading scenarios. The model considers the FGS as a composite member with gradual variation of the volume fraction of its constituents. Creep is accounted for through Boltzmann's principle of superposition, which yields a generalized Maxwell rheological model that is computationally effective (no need to store the entire history) after the expansion of the relaxation function into a Dirichlet series. A numerical procedure for the determination of the variable Maxwell constants through the depth of the member is developed. The model accounts for the geometric nonlinearity through large deformation kinematic relations, and considers the shear deformations of the member. In order to account for the gradual variation of stresses and strains with time, an incremental time-stepping analysis is conducted.

Fig.1 shows the time variation of the transverse deflection of a typical functionally graded beam-column under different load eccentricities, with creep buckling being observed for $e = 0$ and $e = -5.67$ mm. The length of the investigated beam-column is 1000mm with a rectangular cross section of 100mm height and 30mm width. It is subjected to a sustained load that equals 30% of its elastic buckling load. It can be seen that the direction of the load eccentricity exhibits a critical role unlike homogeneous structures or symmetric FGS, which mainly influenced by the absolute value of the eccentricity. Preliminary analysis of the beam-column under bending only has shown that the neutral axis shifts downwards with time due to the variation of the viscoelastic characteristics through the depth. Hence, for eccentricities that are opposite to the direction of shifting of the neutral axis, the structures is much more susceptible to creep buckling. For positive eccentricities, the instantaneous deflection is upwards (negative one). Without shifting of the neutral axis, this deflection is supposed to increase with time due to creep and to remain negative. However, due to the shifting, the effective eccentricity decreases and the load becomes centric one at a certain time (11 days in this example) where the deflection is zero. Beyond this point, the load becomes an eccentric one and tends to increase the positive deflections downwards. These observations exhibit some aspects of the complex structural response and analysis of functionally graded structures.

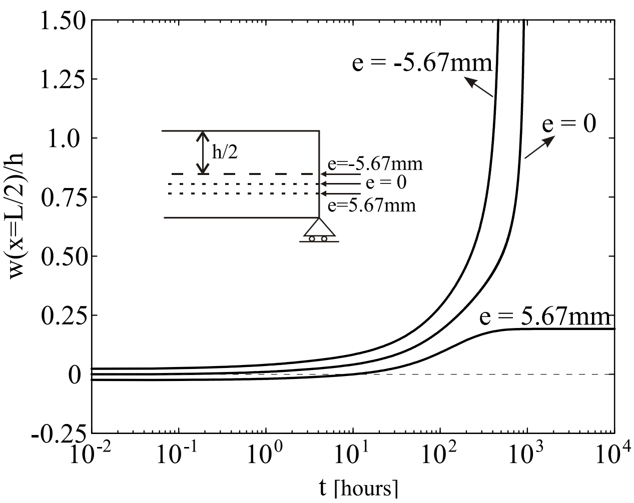

Figure 1: Variation in time of the normalized peak deflection with different eccentricities

REFERENCES

[1] H.S. Shen. *Functionally graded materials: nonlinear analysis of plates and shells*. CRC Press, New York, 2009.

[2] Venkataraman, and B.V. Sankar, Elasticity solution for stresses in a sandwich beam with functionally graded core. *AIAA*, Vol. 41, pp. 2501-2505, 2003.

[3] H.H. Hilton, D.H. Lee and A.R.A. El Fouly, Generalized viscoelastic designer functionally graded auxetic materials engineered/tailored for specific task performances, *Mechanics of Time-Dependent Materials*, Vol. 12, pp. 151-178, 2008.