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Long Term Creep Assessment of Room-temperature Cured Epoxy Adhesive by Time-stress Superposition and Fractional Rheological Model

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Abstract:
The creep behavior of a new type epoxy resin adhesive which is room-temperature cured and used for reinforcing engineering structures was studied. The tensile strength of the adhesive has reached the desired values for the structural adhesive used for bonding concrete as the base material with steel. The short-term creep tests were conducted under four different stress levels. The generalized curve for reference stress was obtained by utilizing the time-stress equivalent principle. Moreover, compared with traditional Burgers model, an improved fractional KBurgers model obtained by replacing the Newton derivative with the fractional derivative element (Abel component) in the traditional Burgers model can capture the creep behavior of this epoxy adhesive with high precision in the condition of the room-temperature and tensile stress of 36 MPa.

Key words:
Epoxy resin adhesive, creep, time-stress equivalence principle, KBurgers model

1 INTRODUCTION

Epoxy resin adhesive is widely used in civil engineering structures and other engineering applications because of its excellent comprehensive performance and good bonding to the surface of materials. The long-term behavior of the structural adhesive has a great impact on the engineering structures which have a design life of several decades or even a hundred years [1]. Therefore, the long-term behavior of the structural adhesive in the certain condition needs to be studied. Obviously, it is impossible to estimate the long-term property according to the method listed in the standard, because it will cost at least several months or even several years. It has been proved that the high temperature and high stress can accelerate the creep rate of materials. In recent decades, temperature, load and physical aging attracted lots of attention were considered to be the main factors of great effect on the creep [2–6] and some accelerated methods developed to assess the long-term creep behavior of epoxy adhesive were mainly the utilization of time-temperature equivalence principle and time-temperature-stress equivalence principle [7–14]. In the past decades, extensive efforts have been devoted to understanding the principle of time-temperature equivalence applied to predict the long-term performance of epoxy adhesive in a short time [15, 16]. Nevertheless, the creep behavior of adhesive was found to be very sensitive to small change in temperature and sometimes in order to obtain data in the certain temperature, tests need to be operated at extremely low and high temperature which cannot be readily realized in the laboratory [17, 18]. On the contrary, it is easier to control and realize the extremely low and high stress in the laboratory. According to the time-temperature-stress equivalence principle, the generalized curve of reference temperature and stress level can be constructed by the short-term creep curve shifted along the time scale. Luo et al. had proved that the time-stress equivalence principle can be deduced from time-temperature-stress equivalence and verified it by experiments [14]. The validity and practicability of the time-stress equivalence principle focused on accelerating the creep behavior of materials were indicated by considerable research [19–21]. Except for temperature and stress, the physical aging, such as hydrothermal aging

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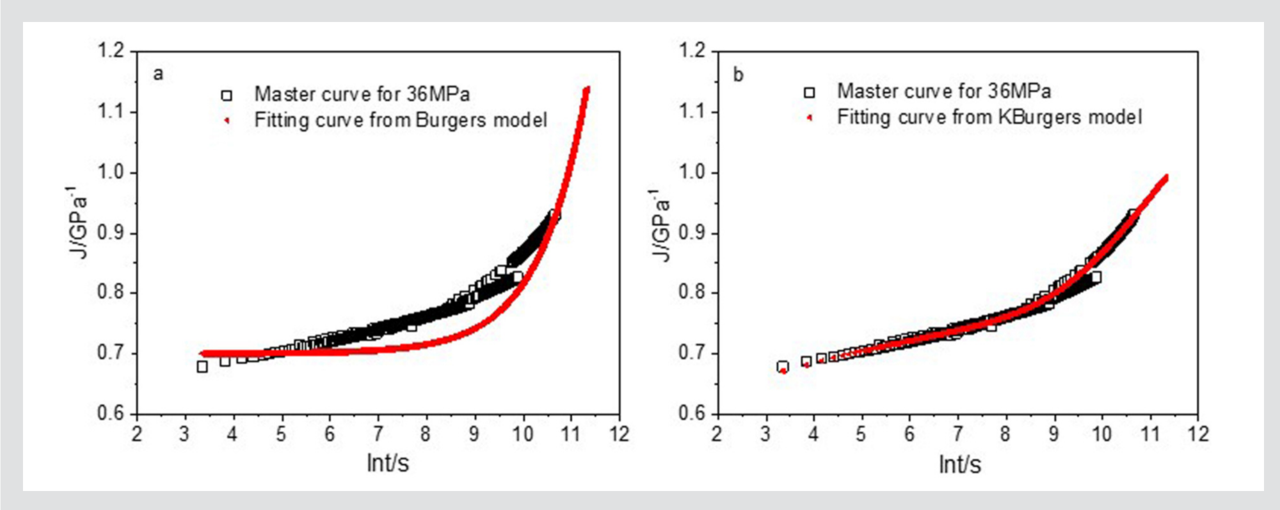

Figure 13: The master creep curve and fitting curve when the stress is 36 MPa: (a) Fitting curve from KBurgers model and (b) fitting curve from KBurgers model.

indicated that the epoxy adhesive was a typical nonlinear viscoelastic material. The generalized curve was obtained by the time-stress equivalence principle in the condition of the room-temperature and tensile stress of 36 MPa. Compared with the Burgers model, the simulation results indicated that the KBurgers model can predict the creep behavior of this new adhesive in the condition of the room-temperature and tensile stress of 36 MPa with high precision. Collectively, the experiments and the model predictions can provide guidance for the various practical applications of the newly developed adhesives in the future. For a new type of material, this study was also an exploratory work, and a lot of work needs to be perfected in the follow-up. For instance, more rheological models, especially fractional order rheological model should be explored which was more suitable for describing this new material in the other conditions.

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