STUDY ON THE CAPACITY OF AGED NATURAL RUBBER BEARINGS

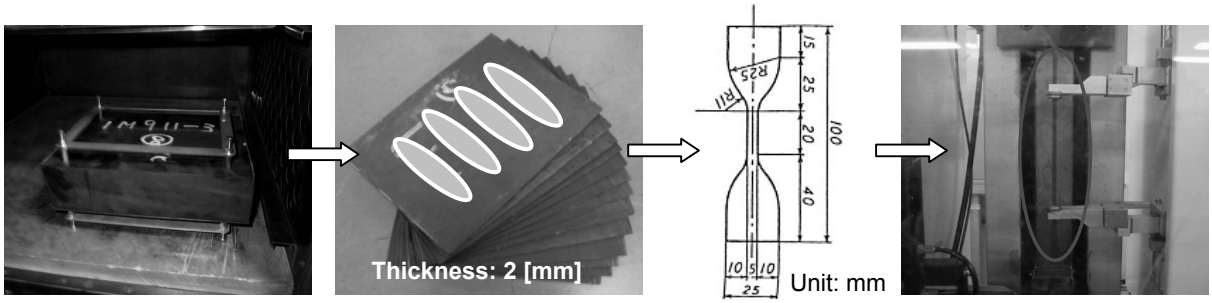
Nagoya University Student Member ○Haosheng Gu
Nagoya University Fellow Member Yoshito Itoh
Tokai Rubber Industries, Ltd. Member Yoshihisa Yamamoto

１．Introduction

Aging results in an increase of hardness of natural rubber (NR) materials, while a decrease of elongation at break or tensile strength. The aging effect therefore not only makes base-isolated rubber bearings become harder, but also reduces their capacity. In this study, the variation of the elongation at break (EB) is investigated through the accelerated thermal oxidation test on NR blocks. Based on the predicted EB at any position inside a base-isolated NR bearing, its long-term capacity is checked using FEM analysis.

２．Thermal Oxidation Test

Fifteen NR blocks with the dimension of 220×150×50mm (length×width×thickness) were accelerated aged in a Thermal Ageing Gear Oven. Three elevated temperatures, 60℃, 70℃, and 80℃ were applied in the oven. **Fig.1** shows the accelerated thermal oxidation test flow. When the rubber block specimen was taken out from the oven, it was sliced into pieces with a thickness of 2mm. From each slice, four specimens with No.3 dumbbell shape were cut out. Then through the tensile tests the EB corresponding to each position inside a NR block can be obtained. The variation of EB vs. its initial state EB_0 in the NR block is plotted in **Fig.2**. It can be found that EB decreases fastest at the block surface, but in the interior exceeding a certain depth (critical depth) EB almost does not change. The variation of EB/EB_0 at the surface is shown in **Fig.3**. The decrease of EB can be expressed by a linear relationship with the square root of time.



(a) Accelerated Test (b) Rubber Slices (c) No.3 Dumbbell Specimen (d) Tensile Test

Fig.1 Accelerated Thermal Oxidation Test Flow

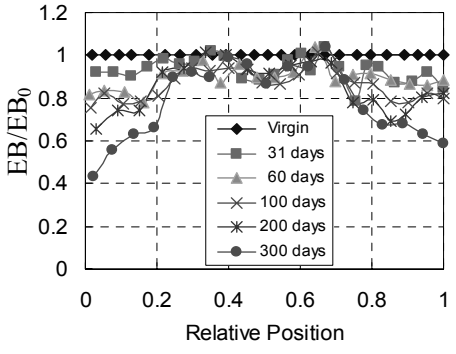


Fig.2 EB Profile in NR Block (60℃)

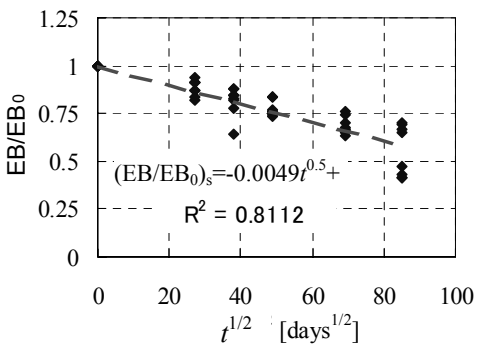


Fig.3 Time-Dependency at Surface

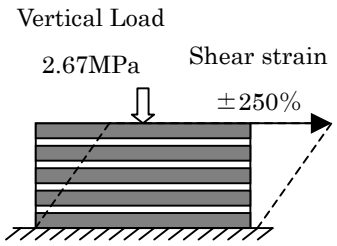


Fig.4 Analysis Condition

キーワード natural rubber bearing, aging, crack, capacity
連絡先 〒464-8603 名古屋市千種区不老町 名古屋大学 伊藤義人 ＴＥＬ052-789-2737

Table 1 Parameters of FEM Model

Dimension [mm]	600×600
Thickness of Rubber Layer [mm]	19
Thickness of Steel Plate [mm]	4.5
Coating Rubber Thickness [mm]	10
Number of Rubber Layer	5
Number of Steel Plate	4
Vertical Load [kN]	960
Horizontal Displacement [mm]	±237.5

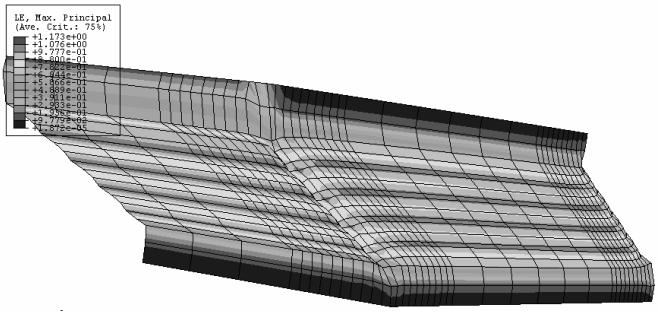


Fig.5 Maximum Logarithm Principle Strain

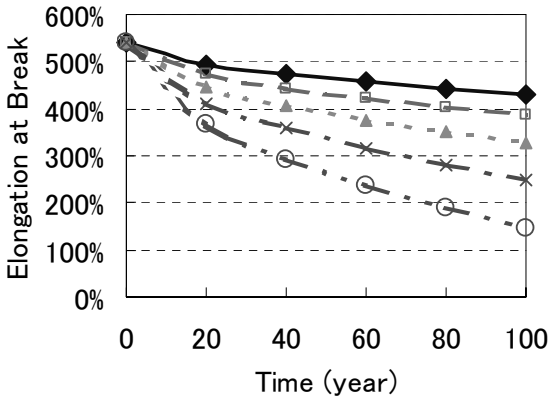


Fig.6 Variation of EB at the Bearing Surface

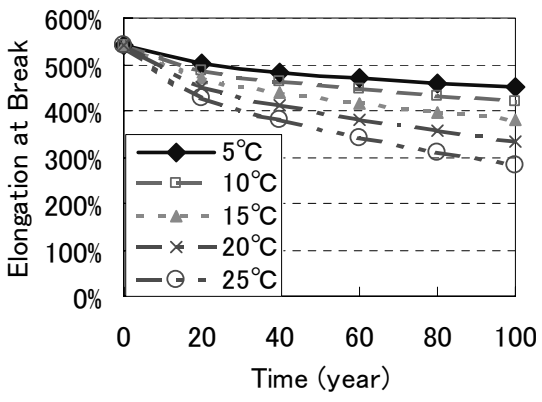


Fig.7 Variation of EB at 10mm to the Surface

The conditions shown in **Fig.4** are applied to the FEM analysis. The parameters of the FEM model are presented in **Table 1**. And the FEM analysis gives the results as shown in **Fig.5**. Since the EB near the surface decreases most greatly, the maximum principle strain in the region close to the surface of the NR bearing is investigated. At the surface the maximum principle strain is about 206%, and at 10mm to the surface is about 209%.

Based on the accelerated thermal oxidation tests on NR blocks, the profile of the EB variation can be estimated using the following equation:

$$EB/EB_0 = 1 + w(EB/EB_0)_s \tag{1}$$

where, EB_0 is EB in the initial state, $(EB/EB_0)_s$ is the variation of EB/EB_0 at the bearing surface, and w is a factor related to the position and the critical depth.

Since the Arrhenius methodology is commonly used to correlate the accelerated aging results with the aging under service conditions, the time in the tests can be converted to the service conditions through the following formula:

$$\ln(\frac{t_r}{t}) = \frac{E_a}{R}(\frac{1}{T_r} - \frac{1}{T}) \tag{2}$$

where, E_a is the activation energy of the rubber (=8.68×10^4[J/mol]), R is the gas constant (=8.314[J/mol· K]), T_r indicates the absolute temperature in the service condition, and T is the absolute temperature in the thermal oxidation test. The symbols t_r and t are the actual time and test time, respectively.

The avearge EB of NR in the initial state is 542.7%. Thus, the decrease of EB at the NR bearing surface and 10mm to the surface are predicted under service conditions, as shown in **Fig.6** and **Fig.7**, respectively. Then the long-term performance is compared with the results of FEM analysis. The EB at the surface is lower than 206% at 25℃ after about 70 years.

3. Conclusion

It is found that in most cases the mechanical cracks will not occur at the surface or inside the aged NR bearings. But if the average temperature at the construction site is higher than 20℃ and the bearing is older than 70 years, the coating rubber may be no longer capable of satisfying its function and cracks will possibly occur under severe earthquakes.