Ageing Mechanical Properties of Some Rubbers Used for Bridge Bearing

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1. Introduction

In recent years rubber bridge bearings have become widely adopted as a means of isolated seismic design. Although the rubber materials are normally thought reliable and long lasting during the design stage, the long-term properties of aged rubbers are seldom investigated due to the lack of enough fundamental experimental data and the limited application history of the rubber bridge bearing.

In this research, systematic accelerated ageing tests have been carried out on four kinds of rubber usually used as the component of the bridge bearing. Different degradation factors like thermal oxidation, ozone, low temperature, ultraviolet, salt water and acid rain were applied in these tests and the mechanical properties were investigated for the time from 0 hour to more than 6000 hours.

2. Accelerated Ageing Tests

Four kinds of rubber materials, Natural Rubber (NR), Chloroprene Rubber (CR), Ethylene Propene Rubber (EPM) and High Damping Rubber (HDR) were provided by four companies. As shown in Fig.1, JIS3 dumbbell specimens made of those rubbers with a thickness of 2mm were used. As the bridge bearing is subjected to the compressive load of the superstructure, the brim of the rubber layer blooms outwards and is in the tensile state. In order to find out the influence of this tensile strain on the ageing process, the specimens were elongated to the strains of 0%, 20% and 40% using a special rig shown as Fig. 2 and kept the pre-strain during the ageing tests.

In the accelerated ageing tests six kinds of environmental conditions were simulated for each kind of rubber material. (Table 1) After each extraction, the mechanical properties like the stresses at 25%, 50%, 100%, 200% and 300% strain, i.e. M25, M50, M100, M200 and M300, the elongation at break (EB) and the tensile strength (TS) were tested.

3. Ageing Mechanical Properties of Four Rubber Materials

It is well known that ageing will usually increase the stiffness of rubbers while decreasing the elongation at break and the tensile strength. From the test results, it is found that the changes of M25 and M50 are relatively less than M100, M200 and M300, but there is no apparent difference among the latter. For simplicity, M100 is taken as the representative stiffness of the rubber. Fig.3 shows the relative changes of the mechanical properties such as M100, EB and TS. The influence of the pre-strain is also compared in this figure.

It can be seen that generally the thermal oxidation changes rubber properties much more than other degradation factors. Although the thermal oxidation test lasts the longest time, in all the ageing tests except for thermal oxidation, properties tend to change little soon after ageing begins. In another word, the saturation state is reached.

Table 1 Conditions of Accelerated Ageing Tests

Material	Pre-strain	Degradation Factor	Test Conditions	Extracting Times (hour)
NR, CR, EPM, HDR	0,20,40%	Thermal Oxidation	70℃	96, 192, 384, 768, 1536, 3072, 6144
		Ozone	Ozone=0.5ppm, 40℃	96, 192, 384, 768, 1536
		Low Temperature Ozone	Ozone=0.5ppm, -30℃	96, 192, 384, 768, 1536
		Ultraviolet Radiation	Radiation+Water spray	360, 720, 1440
		Salt Water Spray	Wetting and drying cycle	360, 720, 1440
		Acid Rain Spray	Wetting and drying cycle	360, 720, 1440

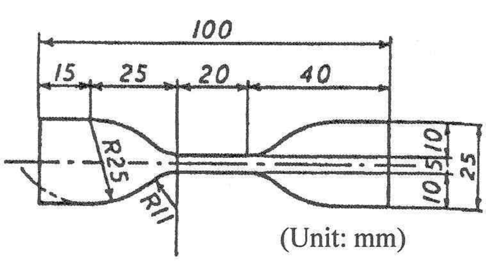

Fig.1 Dimension of JIS3 Dumbbell Specimen

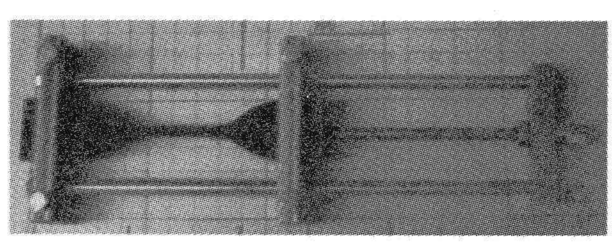

Fig.2 Rig for Pre-straining Rubber Samples

Moreover, in most cases, pre-strain will strengthen the ageing effect to a certain degree, especially when combined with salt water or acid rain, the change of properties will increase by times. However, in the thermal oxidation test a reversed tendency is found, and for EPM and HDR, 40% of pre-strain can make the change of M100 decrease much compared with the case without the pre-strain. Considering thermal oxidation is the severest degradation factor, this decrease accounts for nearly 80% of relative stiffness increase. It proves that for EPM and HDR the pre-strain can counteract a part of ageing effect and shows its favorable aspect during the ageing process.

Among these four rubber materials, M100 of CR and HDR is the most vulnerable to thermal oxidation, which increases by 2 times after about 8.5 months' ageing. The elongation at break of NR and HDR is also likely affected by thermal oxidation, and there's less than half of its original value left by the end of the test. The tensile strength of CR seems not easily affected by all the degradation factors. And EPM has the best ageing resistance, particularly in the tensile state. These basic experiment data will be used to predict the long-term behaviors of rubber using the Arrhenius formula.

4. Conclusions

Accelerated ageing tests considering different degradation factors and strain states were performed on four rubbers usually used in bridge bearings. The variation of each kind of rubber's mechanical properties due to ageing was made clear. Thermal oxidation was proved to be the most important degradation factor. Pre-strain was found to accelerate the ageing process except in thermal oxidation test, and taking the pre-strain into consideration will underestimate the increase of stiffness for EPM and HDR. Compared with other rubbers, EPM is a relatively steadier material.

Reference

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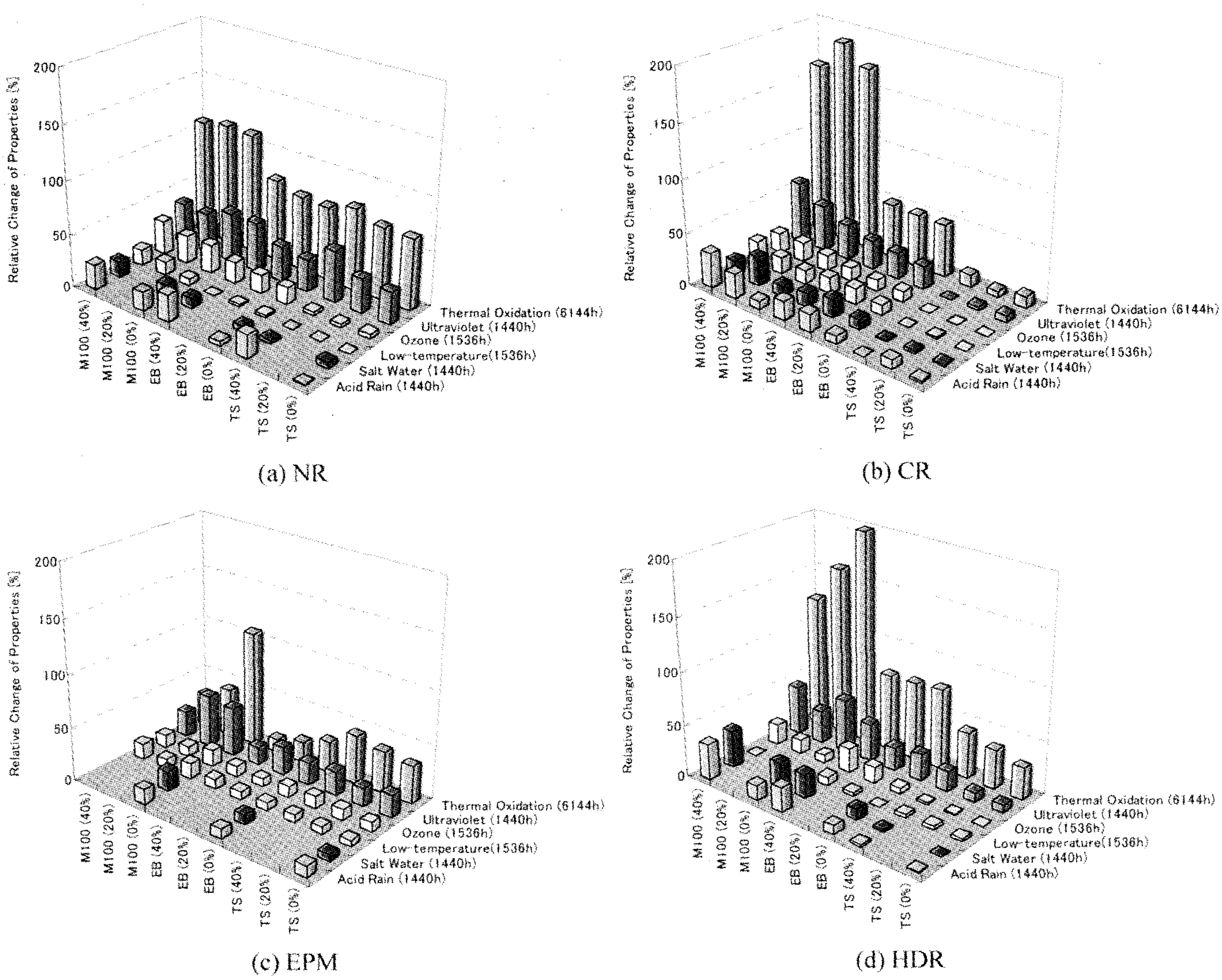

(a) NR (b) CR

(c) EPM (d) HDR

Fig.3 Effect of Ageing on Mechanical Properties