STUDY ON SUNLIGHT DETERIORATION CHARACTERISTICS OF RUBBER BEARING FOR BRIDGES

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１．Introduction

Since Hyogoken-Nanbu Earthquake in 1995, the elastomeric bridge bearings have become preferred in Japan. However, due to the lack of the fundamental data, the long-term durability characteristics of rubber bearing have not been clearly clarified. It has been found that the deterioration of the rubber materials is affected by the factors like heat, ozone, ultraviolet rays, salt water and acid rain, etc. In this paper, the sunlight impact is investigated based on the accelerated deterioration tests. The location and the type of the bridge are taken into consideration for precise results.

２．Sunlight Deterioration

Generally the relative change of the material properties by ultraviolet can be expressed by Arrhenius formula.

$$\ln \frac{y_h}{y_0} = C(It)^a \quad (1)$$

where, y_h is the rubber material properties such as the elongation at the break point, the stiffness and etc. And y_0 indicates the original value of y_h, C, a are constants of rubber material, t is deterioration period, and I represents the ultraviolet intensity and in the test which is 7.75 mW·min·cm^{-2}. In the deterioration test with sunlight, the environment temperature is 50℃. Subtracting the impact by heat, the relationship between ultraviolet radiation and the change of the material property is shown in Fig. 1.

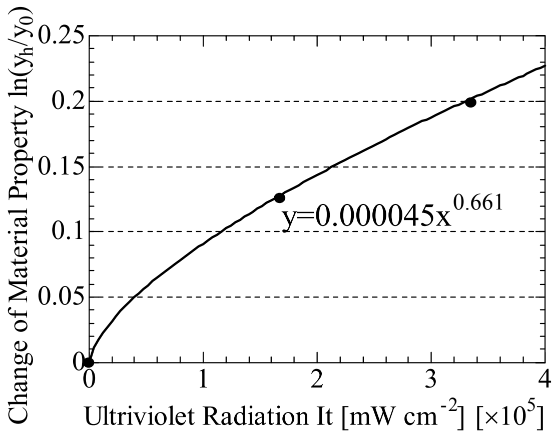

FIG. 1 Relationship between Property Change and Ultraviolet Intensity for NR

To get the ultraviolet intensity in the actual environment, it is needed to calculate the solar radiation to the vertical surface of the rubber bearing. In this paper, it is assumed that the global solar radiation is the sum of the direct and diffuse radiation.

Using Fig. 2, the direct solar radiation flux H_i to a vertical surface can be expressed by the solar radiation to the normal surface H_n using the expression

$$H_i = H_n \cos i \quad (2)$$

$$\cos i = \cos\alpha \cdot \cos\overline{Z} \quad (3)$$

where, α is the solar altitude, $\overline{Z} = Z - P$, where P is the azimuth of the plane, and Z is the sun's azimuth from the south. α and Z can be determined from the following equations.

$$\sin\alpha = \sin L \sin\delta + \cos L \cos\delta \cosh \quad (4)$$

$$\cos Z = (\sin L - \cos L \tan\delta)/\sinh \quad (5)$$

$$\sin Z = (\cos\delta \sinh)/\cos\alpha \quad (6)$$

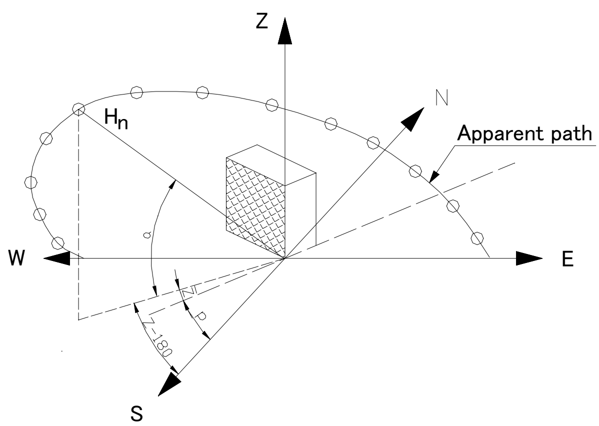

FIG. 2 Angle Diagram for Finding Solar Radiation on Vertical Surfaces

キーワード rubber bearing, bridge, deterioration with sunlight,
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where, L is the northern latitude of the place, δ is the declination of the sun, and h is the hour angle.

The solar radiation data of 2002 at Sapporo, Sendai, Tokyo, Fukuoka, Kagoshima and Naha, published by the National Astronomical Observatory, are used and the direct solar radiation on various oriented vertical planes are accumulated, the average values of which in a day are shown in Fig. 3. From this figure, the maximum direct radiation on a vertical plane and the corresponding azimuth in each place can be determined.

Taking the assumption that the distribution of the diffuse radiation is uniform over the whole of the visible sky hemisphere, the diffuse radiation falling on an inclined plane can be calculated by the following equation.

$$D_i/D_0 = (1+\cos b)/2 \qquad (7)$$

where, D_i and D_0 are the diffuse radiation on inclined and horizontal plane, respectively. For a vertical plane, b equals $\pi/2$ and the diffuse radiation is half of which on a horizontal plane. Ultraviolet is 15.9% of the maximum global solar radiation. From Fig. 4 it can be found that sunlight will obviously accelerate the property change, however, there're no apparent differences among different places.

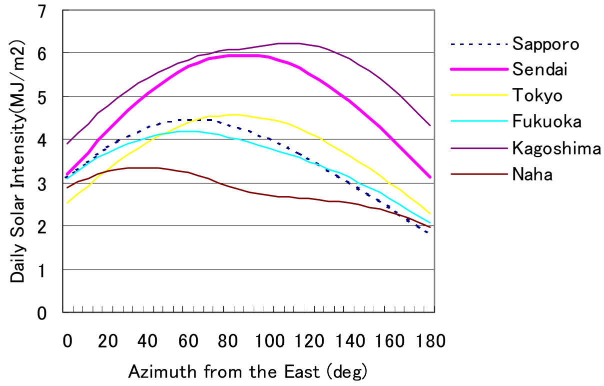


FIG. 3. Daily Direct Solar Intensity of Various Oriented Vertical Planes

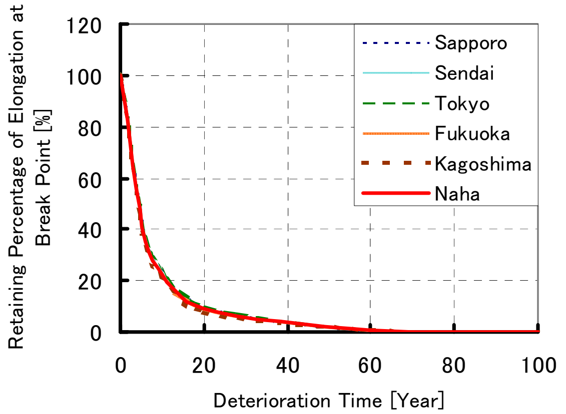
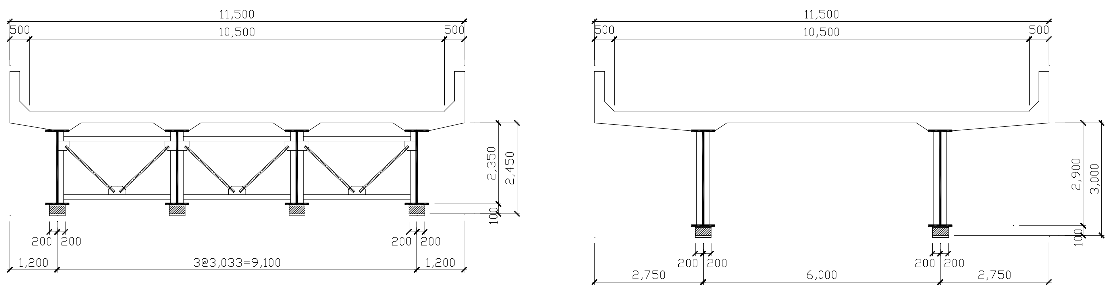


FIG. 4. Property Change by Heat and Ultraviolet



(a) Conventional Bridge (b) Minimized Girder Bridge

FIG. 5. Cross Sections of Typical Bridges

Furthermore, the type of the bridge is considered. Because rubber bearing is usually installed under the girder, it is necessary to estimate the shade effect by the deck. In Fig.5, two typical bridges are introduced and the comparison is shown in Fig. 6. It can be seen that 20% of property corresponds 13 years for conventional bridge while 16 years for minimized girder bridge.

3. Conclusion

The location and the type of the bridge are included to investigate sunlight impact more precisely. It is found that ultraviolet accelerates deterioration process so rapidly that it overwhelms location differences. Meanwhile, sunlight deterioration is faster for conventional bridge than for minimized bridge.

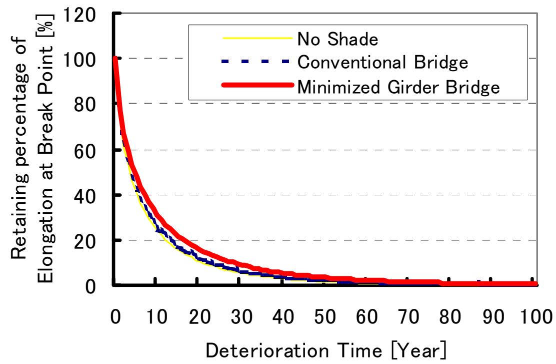


FIG. 6. Property Change of NR at Sendai

Reference

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