

Shear behaviour of laminated neoprene bridge bearing pads under thermal aging condition

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Abstract: The present study was conducted to obtain a better understanding of the variation rule of mechanical properties of laminated neoprene bridge bearing pads under thermal aging condition using shear tests. A total of 5 specimens were processed in a high-temperature chamber. After that, the specimens were tested subjected to horizontal load. The results of shear tests show that the specimens after thermal aging processing are more probably brittle failure than the standard specimen. Moreover, the exposure of steel plate, cracks and other failure phenomena are more serious than the standard specimen. The attenuation trends of ultimate shear strength, shear elastic modulus of laminated neoprene bridge bearing pads under thermal aging condition accord with power function. The attenuation models conform to reality well which shows that this model is applicable and has vast prospect in assessing the performance of laminated neoprene bridge bearing pads under thermal aging condition.

1. Introduction

Neoprene has good aging property [1~3], but its physics-mechanical properties deteriorate under thermal aging condition [4]. There is an already vast amount of research into the effects of heating on the behavior of laminated rubber bearings [5~9]. However, there is a lack of the effects of heating on the behavior of laminated neoprene bridge bearing pads. The impact of climate is more serious to highway bridge rubber bearings than building rubber bearings. The deterioration of mechanical properties of laminated neoprene bridge bearing pads in line with rising aging time is a serious concern, but there is a lack of experimental data on the relationship between increased aging time and its mechanical properties. To confirm the effects of longer aging time caused by thermal aging condition on the mechanical properties of laminated neoprene bridge bearing pads, Shear tests were carried out after specimens processed in high-temperature test chamber for different lengths of time.

2 Experimental Program

2.1 Test specimens

Table 1 Specification of test specimens

specimens	L_s /mm	L_L /mm	T/mm	S	Δl_1 /mm	Δl_2 /mm	t_e /mm	t_1 /mm	t_0 /mm
GJZ200×300×41(CR)	200	300	41	7.17	12.0	16.8	29	8	3

The specimens are denoted by GJZ $L_s \times L_L \times T$ (CR) [10], where GJZ indicates rectangular bridge bearing pads; L_s is the length of short edges of rectangular bridge bearing pads; L_L is the length of long edges of rectangular bridge bearing pads; T is the thickness of rectangular bridge bearing pads; CR indicates bearing pads are made of neoprene; S is the primary shape factor of rectangular bridge bearing pads; Δl_1 is maximal displacement value regardless of brake force; Δl_2 is maximal displacement value considering of brake force; t_e is the total thickness of neoprene layers; t_1 is the thickness of a neoprene layer; t_0 is the thickness of a steel plate layer. The specification of test specimens in detail is described in Table 1.

2.2 Material Properties

All test specimens were made in Chinese Hengshui Xinli Engineering Inc, and the physical and

mechanical properties of specimens in detail are described in Table 2.

Table 2 Physical and mechanical properties of specimens

specimens	hardness (IRHD)	tensile strength (MPa)	elongation at rupture(%)	peeling strength (kN/m)	ultimate shear strength (MPa)	shear elastic modulus (MPa)	elastic modulus of shear (MPa)
GJZ200×300×41(CR)	63	18.4	454	10.6	70	293	1.00

2.3 Thermal aging processing of test specimens

The specimens were first put in high-temperature test chamber to reach 70°C. The distance between the samples is greater than 20mm.

Table 3 Thermal aging processing of specimens

loading modes	specimen	days of thermal aging processing	Dimensions before thermal aging processing (mm)	Dimensions after thermal aging processing (mm)
Shear test	GJZ200×300×41(CR)JYBZ01	0	200×301×43	——
	GJZ200×300×41(CR)JYRF20	20	199×300×41	199×300×40
	GJZ200×300×41(CR)JYRF40	40	200×300×41	199×299×40
	GJZ200×300×41(CR)JYRF60	60	199×300×42	198×298×40
	GJZ200×300×41(CR)JYRF80	80	199×300×42	199×300×40

A total of 10 specimens were tested. There were 0, 20, 40, 60 and 80 days thermal aging processing for specimens. The dimensions of all specimens before and after thermal aging processing were measured according to the method put forward by elastomeric pad bearings for highway bridges [11]. The Dimensions of specimens have no obvious change after thermal aging processing. Test specimens in detail are described in Table 3.

2.4 Test Setup, Instrumentation and Procedure



Fig.1 Photograph of shear testing setup

The shear tests were carried out in the Structural Engineering Laboratory of Shenyang Jianzhu University. The test setup was shown in Fig. 1. The shear load was applied by a 5000kN pressure testing machine.

3 Experimental Results

Fig. 2 shows failure modes of specimens in shear test. The vertical load increased gradually, specimens were in elastic state when the cracks did not appear. Loading were in a short stagnation when a few fine cracks appeared around agglutinate places of steel plates and rubber of specimens' edge. After that, the vertical displacement increased slowly, but the horizontal displacement increased sharply with load increasing. Meanwhile, protrusions appeared around specimens' edge, and the cracks got larger and deeper fast. The vertical displacement and horizontal displacement increased slowly and load declined precipitously when specimens devastated. The layer-crack damage characteristics of specimens were obvious because steel plates broke away from rubber. The specimens after thermal aging processing were more probably brittle failure than the standard specimen. Moreover, the exposure of steel plate, cracks and other failure phenomena were more serious than the standard specimen.



Fig.2 Failure modes of GJZ200×300×41(CR)JYRF40 in shear tests

The mechanical properties of specimens are shown in table 4. The shear capacity, ultimate shear strength and shear elastic modulus of the specimens decreased obviously with the increasing in time of thermal aging processing.

Table 4 the mechanical properties of specimens in shear tests

specimen	shear capacity (kN)	ultimate shear strength (MPa)	displacement corresponding to ultimate shear strength (mm)			displacement corresponding to shear force 200kN (mm)		
			vertical	horizontal longitudinal	horizontal lateral	vertical	horizontal longitudinal	horizontal lateral
GJZ200×300×41(CR)JYBZ01	237.08	3.95	0.35	0.92	26.56	0.18	0.50	20.15
GJZ200×300×41(CR)JYRF20	219.10	3.65	0.27	0.57	8.87	0.27	0.57	7.39
GJZ200×300×41(CR)JYRF40	198.08	3.30	0.29	0.74	9.43	0.29	0.75	9.70
GJZ200×300×41(CR)JYRF60	186.88	3.11	0.33	0.81	8.88	0.34	0.85	10.13
GJZ200×300×41(CR)JYRF80	177.73	2.96	0.31	0.48	7.71	0.35	0.86	10.00

4 Test analysis

The average summer temperature in most parts of the world is 20~30°C. Therefore, the average summer temperature is taken as 25°C. Many tests of rubber bearings on Tomei Expressway which made by Japan Highway Public Corporation showed that those ultimate tensile strength, extension rate and shear modulus after thermal aging processing (60~80°C) of 1,200~2,040 hours would be the equivalent of 100-year thermal aging state at 23°C[12]. Moreover, some tests showed that rubber would be at twice speed of thermal aging when temperature was increased 10°C. The thermal aging processing of 20, 40, 60 and 80 days at 70°C is the equivalent of thermal aging 15,30,45 and 60 years in natural environment.

The test results show that the attenuation trend of ultimate shear strength accords with power function. The attenuation model is acquired by regressing data of experiment with the least square method. Fig.3 shows the attenuation curve of ultimate shear strength of laminated neoprene bridge bearing pads. The attenuation function is shown as follows

$$Z = 5.4848x^{-0.1499} \quad (1)$$

Where, Z is ultimate shear strength; x is years of thermal aging.

4.3 Influence on shear elastic modulus

The measured shear elastic modulus of laminated neoprene bridge bearing pads is summarized in Table 5. The measured shear elastic modulus of standard specimen is 292.42 MPa which is identical to the stipulated index of shear elastic modulus (293 MPa). However, shear elastic modulus of laminated neoprene bridge bearing pads decreases significantly with the increasing in aging time.

Table 5 Measured shear elastic modulus of laminated neoprene bridge bearing pads

Specimen	Measured shear elastic modulus (MPa)
GJZ200×300×41(CR)ZYBZ01	292.42
GJZ200×300×41(CR)ZYRF20	191.52
GJZ200×300×41(CR)ZYRF40	172.34
GJZ200×300×41(CR)ZYRF60	152.66
GJZ200×300×41(CR)ZYRF80	140.41

The test results show that the attenuation trend of shear modulus accords with power function. The attenuation model is acquired by regressing data of experiment with the least square method. The attenuation function is shown as follows

$$G_1 = 1.9128x^{-0.2045} \quad (2)$$

Where, E is shear elastic modulus.

To examine and assess attenuation model and to make statistic analysis with the data by induced into attenuation function, E is 194.72, 166.81, 152.38 and 142.90 when x is 15, 30, 45 and 60, respectively. The average ratio of calculating data to testing data is 1, and its standard deviation and coefficient of variation are both 0.02. The attenuation model of shear elastic modulus conform to reality well which shows that this model is applicable and has vast prospect in assessing the performance of laminated neoprene bridge bearing pads under thermal aging condition.

5 Conclusion

The following conclusions can be drawn within the limitations of the current tests:

- (1) The shear test results show that the specimens after thermal aging processing prone to more brittle failure than the standard specimen. Moreover, the steel plate exposed, cracks and other damage phenomena are more serious than the standard specimen.
- (2) With the increasing in the aging time and the deepening of the degree of thermal aging processing, shear capacity, ultimate shear strength, shear elastic modulus of the laminated neoprene bridge bearing pads decreased dramatically.
- (3) The thermal aging processing has certain effect on vertical stiffness; the thermal aging processing has a greater effect on horizontal equivalent stiffness than vertical stiffness.

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