Damage assessment of High damping laminated rubber bearing
using AI based on acceleration records

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ABSTRACT

Following earthquakes, rapid assessment of damage to road bridges is crucial for There are challenges in traditional methods that direct field assessment is time-consuming and pose challenges such as inaccessibility, risk of secondary disaster, and traffic dysfunction. The given problem statements in that research are the time sensitive nature of damage assessment requires a more efficient and time-consuming method. The given problem statements in that research are the time sensitive nature of damage assessment requires a more efficient solution. And advantages of acceleration sensors are acceleration sensors on road bridges can expedite the assessment process, providing real-time data without the need for field visits. Moreover, issues with previous methods are earlier attempts using cameras faced challenges including limitations during nighttime and excessive cost. But acceleration sensors offer a cost-effective alternative, and advancements in manufacturing have made them more accessible. In previous research, a neural network successfully reproduced the displacement response of seismic isolation bearings from the acceleration response recorded by acceleration sensors installed on bridges during an earthquake dynamic analysis software to determine the damage of bridges. However, it is difficult to implement this method as it is because the acceleration data taken by actual sensors is expected to contain various kinds of noise and measurement errors. In consequence, in this research we aim to leverage AI for damage assessment using acceleration records from experimental subjects. The AI is designed with a neural network that takes acceleration data as input and predicts the displacement of experimental body as output.

1. Purpose

In a previous study, a neural network was successfully used to reproduce the displacement response of seismic isolation bearings from the acceleration response recorded by acceleration sensors installed on bridges at the time of an earthquake using dynamic analysis software to determine the damage of bridges [1]. However, it is difficult to implement this method as it is because the acceleration data taken by actual acceleration sensors is expected to contain various noises and measurement errors. In this study, we applied simulated seismic waves to a seismic isolation bearing in a seismic table experiment, and trained AI to use the acceleration obtained from the attached acceleration sensor as an input factor and the relative displacement obtained from laser displacement meters attached to the top and bottom of the bearing as an output factor to verify whether the relative displacement response can be reproduced for the unlearned data. The AI was trained to reproduce the relative displacement response of the unlearned data.

2. Contents

2.1 Shaking table experiment

In the shaking table experiment, an actuator acting from the lateral direction was used to shake the shaking table, and an acceleration sensor and laser displacement meter were installed on a specimen with a roller installed between the base platform and the weight to evaluate damage to the specimen. The specimen was a high- damping laminated rubber bearing with dimensions of 10 mm × 110 mm × 73 mm, consisting of steel plates stacked (thick is 4mm) in four layer high-damping rubber. 9.57 kN weight was attached to the top and a 100 kN actuator was used. Random waves of 5 seconds duration were shaken 100 times. The experimental apparatus and instrumentation setup are shown in Figures 1 to 4. Random waves were generated using the spectral matching method, and low- pass filtered to remove DC and long-period components.

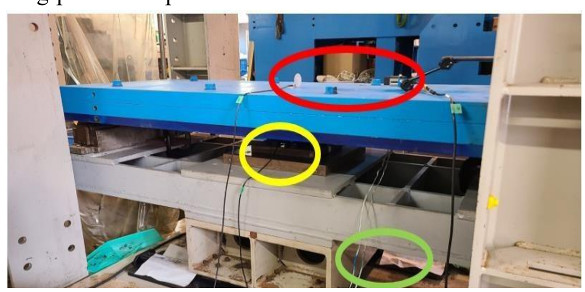

Figure-1 Setup status

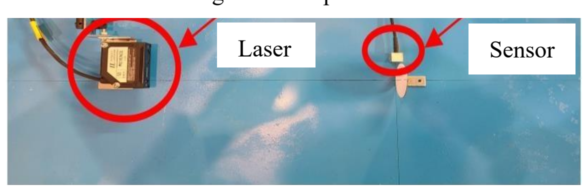

Figure-2 Sensor installation

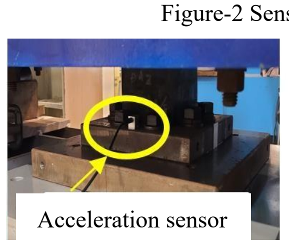

Figure-3 Bearing part

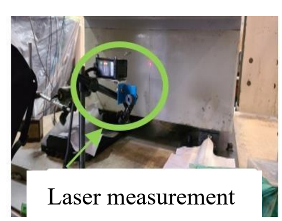

Figure-4 VT part

2.2 Neural network (NN)

NN consists of an input layer, an intermediate layer, and an output layer. Generally, there is one input layer, one output layer, and one or more intermediate layers. The used in this study uses the acceleration response of the upper and lower weights as input factors and the deformation of the seismic isolation bearing as output factor. The number of intermediate layers was set to 1 to 3, the number of nodes the intermediate layers to 10 to 100, and the number of training cycles was set to 1 million. The parameters were updated using the Adam method [2], and the ReLU function [2] was used as the activation function. [2]

Data were normalized to a range of -1 to 1 (Figure-5).

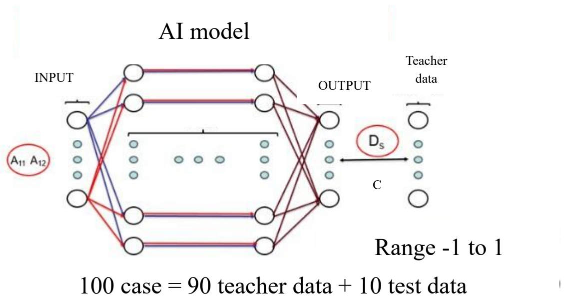

Figure-5 Input-outpuct factors and construction NN

2.3 Teacher and test data

The random waves obtained in the experiment were randomly divided into 90 cases of teacher data and 10 cases of test data for training. The data were preprocessed by applying a 15Hz low-pass filter to the acceleration to remove noise. When training a neural network, appropriate filtering is necessary because learning does not proceed well with data containing measurement errors. Therefore, the acceleration was Fourier transformed, and the time and frequency regions before and after the filter was used.

2.4 Damage assessment bearing by NUM calculation

Figure-6 shows the results of comparing the displacement obtained by second-order time integration of the acceleration measured in the actual experiment with the displacement measured in the experiment at the same time. It was found that the ratio of the integral value in the mathematical calculation to the experimental value is in good agreement.

2.5 Damage assessment of bearing by NN

Figure 7 shows the results of a validation test using untrained data for an NN with three intermediate layers and 40 nodes, as an example. The results show that the estimated values by NN and the experimental measurement results generally agree in terms of both peaks and phases. The errors in the peak values when 10 waves of validation data are input for NN trained with no preprocessing data and NN trained with preprocessing data, respectively.

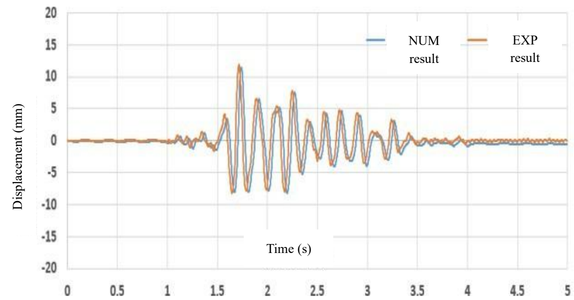

Figure-6. Comparison of numerical and experiment

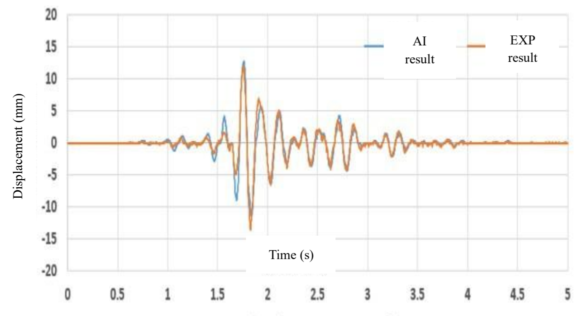

Figure-7. Comparison of AI and experiment

Conclusion

In this study, the deformation of the seismic isolation bearing was reproduced by NN from the acceleration recorded by actual acceleration sensors through shaking table experiments. The accelerations recorded by the accelerometers were time-integrated on the 2 level and compared with the displacements measured in the actual experiments. The following conclusions were drawn from this study.

(1) As a result of comparing NN and numerical calculations, it was confirmed that AI can reproduce almost the same results as numerical calculations.

(2) It was confirmed that cutting unnecessary frequencies in the acceleration recordings by preprocessing the data improves the reproduction accuracy.

Future challenges

Comprehensive evaluation and validation of the proposed HDR model within full-scale structural systems or real building environments, advanced structural analysis tools such as LIRA-SAPR, with the objective of rigorously assessing its accuracy, reliability, and applicability under practical engineering conditions.[3]

References

[1] Shuya Miyatake: Damage displacement of bridges based on acceleration response using neural network, 2022
[2] Yasutake Saito: Building Deep Learning from Zero2016
[3] Sosorburam Purevdorj: Master’s degree of MUST 2025