Research to Gain Understanding of the Sense of Scale of Structure Damage Directly after Earthquakes

(Research period: FY2009-)

Earthquake Disaster Management Division, Road Structures Department

Researcher NAKAGAWA Takuma Head NAKAO Yoshihiro Senior researcher NAGAYA Kazuhiro

(Keywords) disaster response, gathering disaster information, acceleration response spectrum

1. Introduction

When a large-scale earthquake occurs, road administrators conduct patrols to gather information about the extent of the damage, but as it takes time to confirm the damage, a period without information arises.

As part of initiatives relating to gathering information about damage in the period without information, the National Institute for Land Infrastructure Management (NILIM) is trialling initiatives to automatically distribute information inferring the sense of scale of structure damage focusing on acceleration response spectra (below, "spectrum analysis information") to disaster response personnel and others approximately eight minutes after an earthquake occurs. This paper presents an outline of spectrum analysis information.

2. Background and outline of spectrum analysis information

Seismic intensity is one piece of information that is available directly after an earthquake occurs, but because the period of the seismic motion, which significantly affects the computation of the seismic intensity, differs from the natural period at which public works structures are affected by strong vibrations, it has been pointed out that the seismic intensity does not necessarily match with significant damage to public works structures.

Given this, the researchers in this study

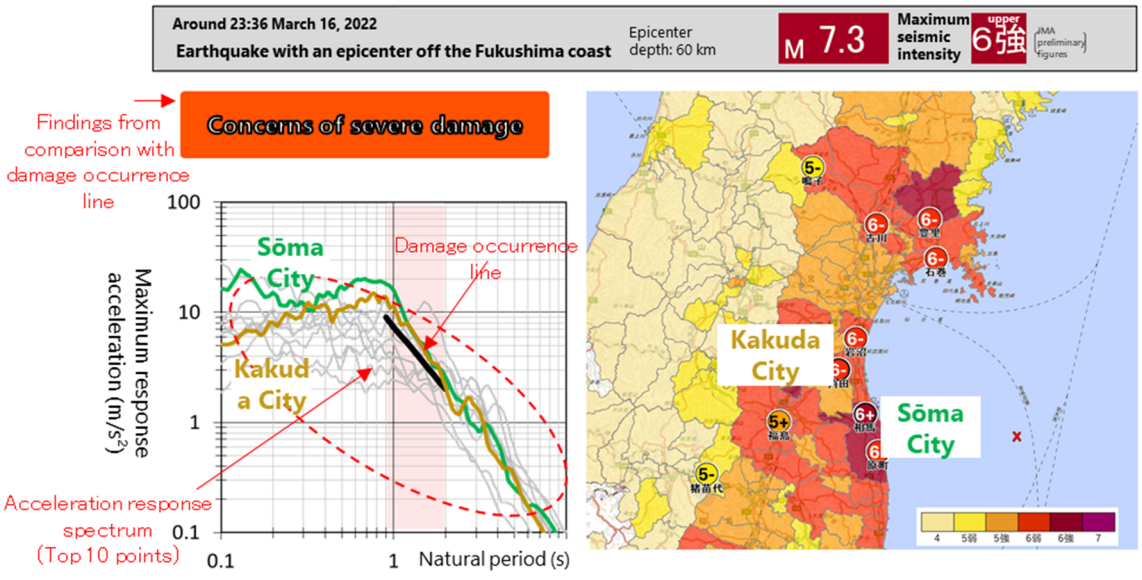

Fig. 1. Example of spectrum analysis

thought it may be possible to gain an understanding of the sense of scale of damage to structures by focusing on natural periods between 0.9 and 2 seconds, which highly correlate to structural damage, within the acceleration response spectrum, which shows the maximum response acceleration of the elastic response computed by having seismic motion operate on structures with various natural periods. Specifically, this method gains information about the sense of scale of structural damage due to an occurring earthquake by comparing the "damage occurrence line" that is defined based on the accelerated response spectra obtained in previous earthquakes when damage was limited with the acceleration response spectra of the seismic motion measured at seismographs throughout Japan when a new earthquake occurs (see fig. 1). We have built a system to create and distribute this spectrum analysis information automatically and have implemented automatic distribution.

3. Comparing spectrum analysis information and actual damage

The acceleration response spectrum shown in figure 1 is from an earthquake off the coast of Fukushima with a maximum seismic intensity of 6 upper that occurred late in the night of March 16, 2022. This earthquake surpassed the damage occurrence line at nine observation points. As vibration surpassing the damage occurrence line was observed throughout the entire region at a natural period of 0.9 to 2 seconds, which correlates strongly with structural damage, at the two observation points in the cities of Sōma and Kakuda in particular, we inferred "concerns of severe damage" from the spectrum analysis information.

As a result of patrols by the road administrator after the earthquake, road surfaces had developed differences in level on the E6 Jōban Expressway and National Highway 6 in Sōma. Furthermore, in Kakuda, the substructure of the Edano Bridge on a municipal road was damaged (photo 1) and the bridge was closed to traffic for approximately three months until stopgap recovery works were completed, which shows that the spectrum analysis information was able to accurately infer the sense of scale of the damage.

Photo 1. Edano Bridge in Kakuda City, which was damaged by an earthquake

4. Contributing to lessening burdens on the ground

Road patrols after earthquakes have been conducted as a trial initiative from FY2019, and spectrum analysis information has been given a new position within them.

Conventionally, directly managed national highway offices that measure an earthquake with a seismic intensity of 4 or higher are required to conduct road patrols for emergency inspection "immediately" after the earthquake occurs, but partly because of the construction of an environment where information on the sense of scale of structural damage is

distributed approximately eight minutes after an earthquake due to spectrum analysis information, the response when an earthquake with a seismic intensity of 4 occurs is being changed in a trial. Specifically, they are trialling operations where, if there are no concerns about damage occurring due to recent weather and other factors and the concerns about damage occurring are minor due to the result of the spectrum analysis information, inspections are conducted in "the road patrols in normal hours on the day of or the day following the occurrence of the earthquake." (Operations in the case of an earthquake with a seismic intensity of 5 lower or higher has not changed.)

In other words, the spectrum analysis information is being used, and it appears that it is leading to lesser burdens on the ground, including for road administrators and the affiliated companies that are contracted for maintenance and management operations, etc.

Over the 12 months of FY2021, 43 earthquakes with a maximum seismic intensity of 4 occurred throughout Japan. Of these, 11 occurred during working hours (8:30-17:15 on weekdays), while the other 32 occurred outside working hours on a weekday or at any time on a holiday. This is thought to have changed 32 initial responses on the ground just in this one year, and it could be considered to have contributed to DX in disaster response.

5. Conclusion

This paper presented the background to spectrum analysis information, which infers the sense of scale of structural damage focusing on acceleration response spectra, and a comparison with actual damage, as part of initiatives to fill in the period without information directly after an earthquake.

The automatic distribution of spectrum analysis information began in FY2017, but since then, we have made improvements to the system with the aim of increasing immediacy and stability of the distributions and enriching the content that is distributed. In FY2022, we moved the system server onto the cloud to enable stable distribution in the event of a large-scale earthquake and made general improvements to the system. We intend to continue the automatic distribution initiative while validating the accuracy of the inferences, among other work.

☞See here for detailed information

1) Tech. Note of NILIM, No. 1204, *Automatic Delivery System of Earthquake Spectrum Analysis Information: Outline of the System and Validation*
http://www.nilim.go.jp/lab/bcg/siryou/tnn/tnn1204.htm

2) Nakagawa Takuma, Nakao Yoshihiro, Nagaya Kazuhiro: Gaining Understanding of the Sense of Scale of Structure Damage in the Period Without Information Directly after Earthquakes, *FY2022 Proceedings of the Land Technology Research Society, MLIT*, p. 5, Nov. 2022

3) Nakagawa Takuma: Providing Information on the Sense of Scale of Structure Damage Directly after Earthquakes: Improving Spectrum Analysis Information of Seismic Motion to Supplement the Period Without Information, *Civil Engineering Journal*, pp. 53-54, Oct. 2022