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Analysis of Causes of Differences in Tremors Affecting Hamaoka Nuclear Power Station during Suruga Bay Earthquake (Overview)

By means of a survey of the characteristics of underground structures (additional survey) conducted in response to the Suruga Bay earthquake in August 2009 and analyses of seismological monitoring records, Chubu Electric is analyzing the causes of differences in tremors that have affected its power generation facilities during the earthquake. As the survey results and evaluations are compiled, they are reported to a government Working Group[*1]. The present report compiles details of this analysis of causes of differences in tremors affecting the facilities that have already been reported. An outline of the results of the assessments is provided below.

1 Results of analyses of seismographic records, etc., and narrowing down of potential causes

(1) Results of seismological monitoring of Suruga Bay earthquake

The Suruga Bay earthquake that occurred in August 2009 had its seismic center at a point 37.0 km (epicentral distance) in a northeasterly direction from the Hamaoka Nuclear Power Station. The tremors in bedrock at Reactor No. 5 were measured as approximately twice as intense as those recorded at Reactors No. 3 and 4. Amplification of the tremors at Reactor No. 5 was also observed in a narrow band close to a period of 0.3-0.5 sec., but from 0.5 sec. the tremors became similar to those recorded at other reactors on the long-period side.

(2) Results of analysis of seismic records by direction of arrival

The main shock and the aftershocks occurring close to it in the Suruga Bay earthquake produced differing tremors in reactors (No. 4 and 5) separated by only approximately 400 m. However, in the case of earthquakes occurring at a greater distance from the facility and seismic waves arriving from different directions, the tremors at Reactor No. 5 are similar to those at other reactors.

(3) Narrowing down of causes

The characteristics of the monitoring records for the Suruga Bay earthquake suggested that the main factor producing the more intense tremors at Reactor No. 5 than the other reactors was a shallow underground structure of a depth of less than several hundred meters close to the reactor site.

2 Results of survey of characteristics of underground structures (additional survey of shallow underground structure)

The results of part of the survey of the characteristics of underground structures (additional survey) have indicated the existence in the Sagara layers (alternating layers of sandstone and mudstone), as a localized structure, of alternating sandstone-dominant layers in which the proportion of sandstone exceeds 50%. Subsequent survey results indicated the existence of a “low-velocity layer,” sitting atop the alternating sandstone-dominant layers, that slowed the velocity of the S-waves by approximately 30% against the surrounding bedrock, from 300 to 500 m below Reactor No. 5.

Based on the fact that a seismic reflection survey showed results corresponding to part of a sedimentary layer with a distinctive profile, among other data, it is believed that this “low-velocity layer” is locally distributed in an eastward direction from the vicinity of Reactor No. 5 to the exterior of the facility site.

3 Results of analytic studies and causes of amplification of seismic excitation

A ground model that reflected the distribution of the “low-velocity layer” was formulated, and the effect of the layer on the amplification of seismic excitation at Reactor No. 5 was studied. The results of this analysis suggested that, given that a difference was observed in the vicinity of Reactor No. 5 in the case of the tremors from the direction of the main shock of the Suruga Bay earthquake, the “low-velocity layer” was the main factor resulting in the greater intensity of the tremors at Reactor No. 5 during the earthquake.

4 Summary

A “low-velocity layer,” sitting atop the alternating sandstone-dominant layers, that slowed the velocity of S-waves (seismic waves) by approximately 30% against the surrounding bedrock was identified from 300 to 500 m below Reactor No. 5. This “low-velocity layer” is believed to be locally distributed in an eastward direction from the vicinity of Reactor No. 5 to the exterior of the facility cite.

The results of an analysis using a ground model that reflected the distribution of this “low-velocity layer” suggested that, given that a difference was observed in the vicinity of Reactor No. 5 in the case of the tremors from the direction of the main shock of the Suruga Bay earthquake, the “low-velocity layer” was the main factor resulting in the greater intensity of the tremors at Reactor No. 5 during the earthquake.

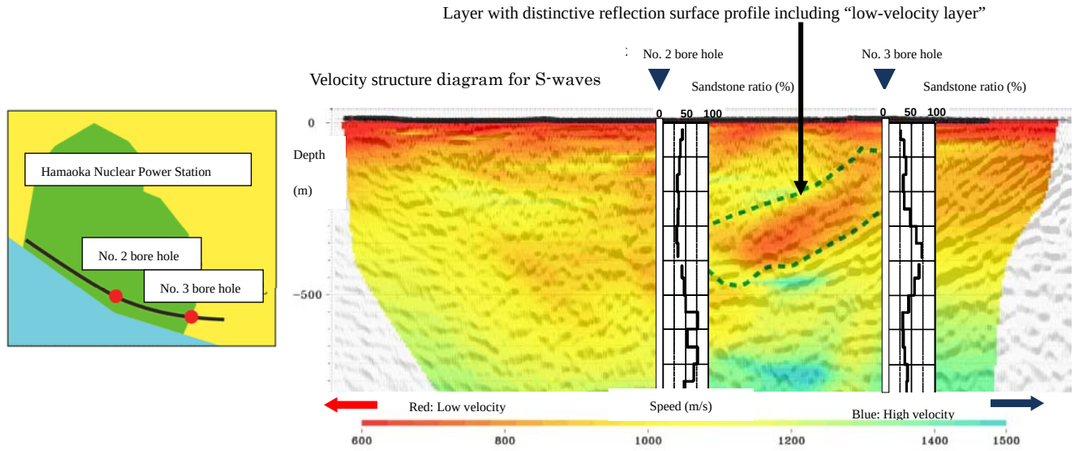
In future, Chubu Electric will comprehensively analyze the results of various surveys, attempt to increase the accuracy of the pattern of distribution and substratum properties of the “low-velocity layer” in the analytic model, and study the characteristics of amplification of seismic excitation.

*1 The government Working Group is a Joint Working Group on Earthquake, Tsunami, Geology, and Ground Foundation under the Seismic and Structural Design Subcommittee, Nuclear and Industrial Safety Subcommittee, Advisory Committee for Natural Resources and Energy.

*2 Offset vertical seismic profiling (VSP) is a method of surveying underground structures by generating elastic waves at the surface of the earth by means of vibroseis vehicle, etc., that are recorded by geophones positioned in bore holes. It enables knowledge of underground structures distant from the bore holes to be obtained.

[Concerning the “low-velocity layer”]

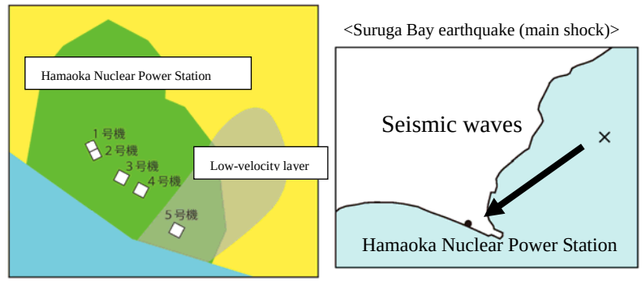
The results of an offset VSP survey[*2] using the deepest bore holes, Nos. 2 and 3, indicated the existence of a “low-velocity layer” that reduced the velocity of the S-waves by approximately 30% against the bedrock between the holes.



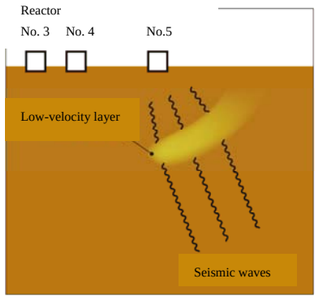
This “low-velocity layer” sits atop the alternating sandstone-dominant layers 300-500 m below Reactor No. 5, and has a sandstone ratio of approximately 40%.

[Concerning amplification of seismic excitation]

The “low-velocity layer” is locally distributed in an eastward direction from the vicinity of Reactor No. 5 to the exterior of the facility, and it is thought that this was the cause of the amplification of seismic waves at Reactor No. 5.

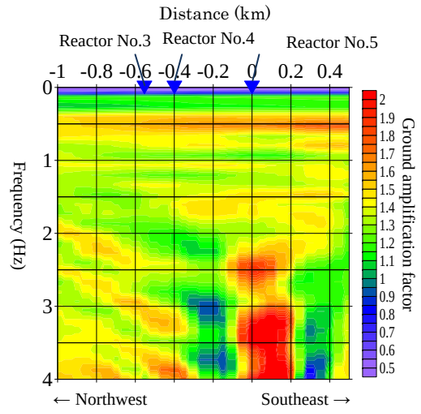


<Image of amplification of seismic waves>



During the Suruga Bay earthquake (main shock), amplification of seismic waves was observed at Reactor No. 5, but not at Reactors No. 3 and 4. In addition, an analysis of seismological monitoring records shows that the differences produced as a result of the direction of arrival of the seismic waves are smaller for Reactors No. 3 and 4 than for Reactor No. 5, and no conspicuous amplification of seismic waves has been recorded for these reactors in earthquakes up to the present.

The results of an analysis using a ground model that reflected the distribution of this “low-velocity layer” showed that in the case of the tremors from the direction of the main shock of the Suruga Bay earthquake, a difference was observed in the vicinity of Reactor No. 5.



In the vicinity of Reactor No. 5, the ground amplification factor was higher, and a difference in tremors was observed.

* The ground amplification factor is the amplification rate at the ground surface in response to input. Hz represents “Hertz,” the units of frequency. In terms of the accuracy of the analysis, evaluations are conducted in a range of 0-3 Hz.