Seismic response observed at the IIS earthquake centre during the 11 August 2009 Suruga Bay earthquake

Muneyoshi NUMADA[1], Miho OHARA [2], Kimiro MEGURO[3] and Kiyoshi TAKANO[4]

ABSTRACT: On August 11, 2009, a magnitude 6.5 earthquake occurred in the center of Suruga Bay in Shizuoka Prefecture at a depth of about 23 kilometers. There were few causalities and little damage to buildings in Shizuoka Prefecture. The main reason why the structural damage was not so heavy was due to the short-period wave. The Institute of Industrial Science (IIS), University of Tokyo, observed the seismic response by acceleration meter. The response spectra of the main shaking were calculated and the relationship between the ground motion and structural response determined.

Key Words: Tokai earthquake, IT seismographs, ground motion, structure response

INTRODUCTION

On August 11th, 2009, at 5:07 AM, an earthquake of magnitude 6.5 and focal depth of 23 kilometers, with an epicenter in Suruga Bay in Shizuoka prefecture, occurred. A maximum JMA intensity of six was observed at Izu, Yaizu, Makinohara and Mifunebashi. The Early Earthquake Warning System, installed in 2007, issued warnings 3.8 seconds after the occurrence of earthquake.

The possibility that this was a Tokai Earthquake was considered after the earthquake occurred, but ultimately it proved not to be since the Suruga Bay earthquake was an in-slab earthquake on a reverse fault and the scale was lower than magnitude 8. The Tokai Earthquake should be a trench earthquake from the Philippine plate.

Human damage due to this earthquake were few, with one casualty and 125 injuries (117 in Shizuoka, 3 in Aichi, 4 in Kanagawa and one in Tokyo). The single casualty was caused by suffocation due to thoracoabdominal oppression; the victim was trapped under collapsed books inside a house. Injuries were mainly due to overturned furniture. A total of 5,382 buildings were partially damaged. Three fires broke out (Shizuoka-shi, Kakegawa-shi and Kikukawa-shi), but were extinguished. Atomic power plants No. 4 and 5 were affected and the radiation alarm was activated.

Tokaido Shinkansen was briefly stopped, but service restarted at 8:00 AM on August 11th. The Tomei Highway was blocked until August 15the due to the collapse of road shoulder for roughly 40 meters near the Makinohara interchange. This had a large effect on traffic because it was during rush hours. There was no damage to gas production facilities, but nine gas leakages were observed in Shizuoka-shi. 9,500 houses were blacked out, but power was restored at 13:00 PM on August 11th. Water supply was cut for 72,762 houses in Shizuoka and 2,053 houses in Kanagawa, but restored at 16:00 PM on August 13th. A 0.6-meter high tsunami was observed in Yaizu at 5:13 AM, but there was

[1] Research associate, International Center for Urban Safety Engineering, The University of Tokyo
[2] Associate professor, Center for Integrated Disaster Information Research, The University of Tokyo
[3] Director/ Professor, International Center for Urban Safety Engineering, The University of Tokyo
[4] Professor, Center for Integrated Disaster Information Research, The University of Tokyo

no damage due to tsunami. All tsunami warnings were taken back by 7:13 AM.

The seismic energy in this earthquake was about 1/180th that of the expected Tokai earthquake (predicted to be of M8 class) and the range of the dominant period was smaller than 0.5 seconds or less (**Figure 1**). Also, damage due to this earthquake (the number of casualties, damage to social infrastructure and economic loss) was far smaller compared to the predicted damage from the future Tokai earthquake. In past earthquakes, the component of seismic ground motion which lasted longer than one second caused extensive damage to structures.

This paper shows the dynamic characteristics of the Institute of Industrial Science (IIS) building, University of Tokyo, which is located roughly 120 kilometers from the earthquake epicenter. These data were obtained by analyzing the response record of ground motion and building due to this earthquake, which was observed by IT seismograph and earthquake response observation and analysis system installed in the IIS building.

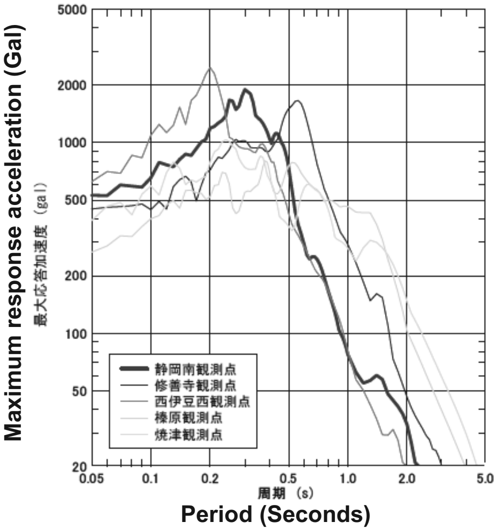

Figure 1. Acceleration response spectra

Overview of Earthquake Response Observation in IIS building

The International Center of Urban Safety Engineering (ICUS) set 18 IT seismographs in IIS in 2007 (**Figure 2**). The IT seismograph was developed by Takano, and contains an accelerometer, filter, amplification equipment, AD translator and LAN port for data transmission. In 2007, 32 earthquakes were observed, with the Niigata Chuetsu-Oki Earthquake the largest of these.

In addition, earthquake response observation systems were installed at the Komaba Research Campus: 7 in the building and 6 under the ground, as well as at the Chiba campus. All data was managed in the basement of the IIS building. A servo-type accelerometer for super structures and underground were also prepared. The servo-type accelerometer is a 3D borehole seismometer, with the range of 0-±2000 gal and frequency characteristic of 0.05-30 Hz.

As explained above, the IIS building has 25 seismographs in the building and 6 seismographs underground. This allows the earthquake intensity to be measured in real time and enables quick safety response for the staff members. In addition, dynamic features of the IIS building can be detected from the daily observations, which is useful for proper disaster prevention measures.

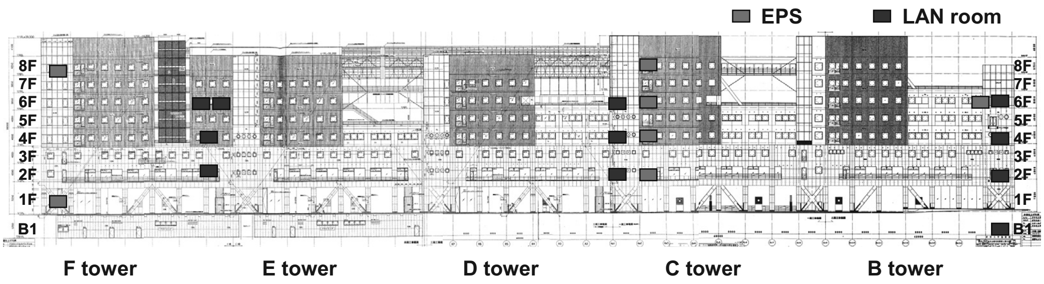

Figure 2. IT seismographs in the building of IIS

Observation results

Ground motion

Figure 3 shows the ground condition and the position of the servo accelerometer in depth at ground surface. N value is over 50 and S wave velocity exceeds 300 meters/second at 18-meter depth, where the 18-meter ground depth can be defined as the engineering bedrock. The accelerometer is set up in the deepest location at 55 meters. **Figure 4** shows the ground amplification characteristics on the ratio of peak acceleration amplification at the 55 meter depth. **Figure 5** shows the spectrum ratio of ground surface to the 18-meter deep bedrock. The peak value of the spectrum ratio in the NS direction was 0.26 seconds and in the EW direction 0.26 seconds and 0.32 seconds are predominant.

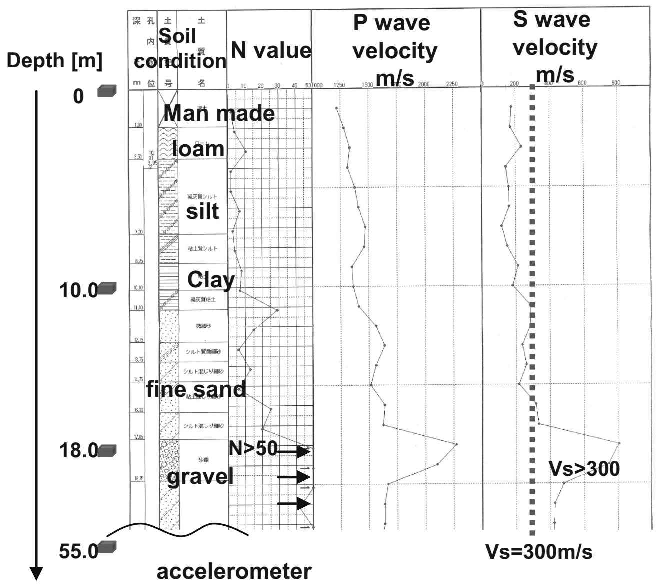

Figure 3. Ground condition and servo-type accelerometer

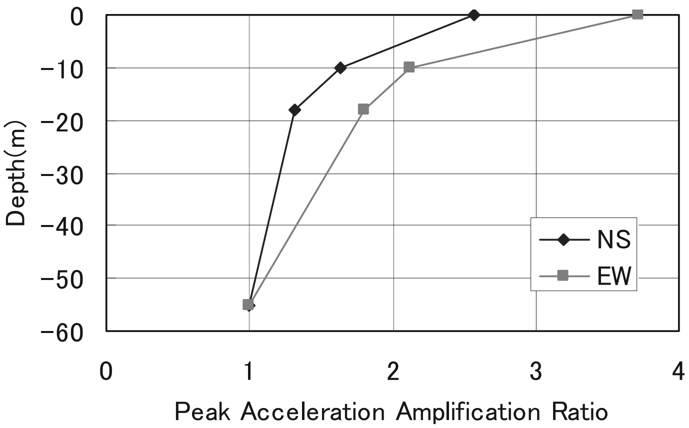

Figure 4. Peak acceleration amplification ratio

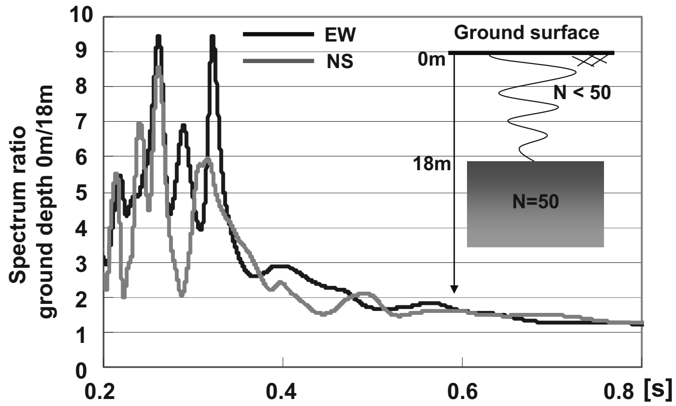

Figure 5. Spectrum ratio of ground surface and 18m depth

Structure

Figure 6 is a seismic wave measured by an IT strong motion seismograph on the 8th floor of building-F. The maximum acceleration is 62.28 gal in the east-west direction. **Figure 7** is a seismic wave observed at the ground surface at the IIS sports grounds. The maximum acceleration is 28.67 gal in the east-west direction.

Table 1 shows the maximum acceleration (gal), the dominant period (s) of IIS building and the instrumental seismic intensity. The dominant period is obtained from the peak value of the spectrum of the acceleration. In the 8th floor of the EF-multistory building, the dominant period records 0.57 seconds in the E-W direction and 0.50 seconds in the N-S direction. **Figure 8** shows the spectrum ratio from the 8th floor of F-building and from the ground surface. From this result, the dominant period is estimated at 0.56 seconds in the E-W direction and 0.51 seconds in the N-S direction.

The IIS building is structurally divided into four sections: BCD-multistory (west side), BCD-building (east side), EF-multistory (west side) and EF-building (east side).

BCD-multistory recorded a maximum acceleration of 93.75 gal on the 8th floor in the E-W direction and a dominant period of 0.54 seconds in the E-W direction and 0.42 seconds in the N-S direction. BCD-building recorded a maximum acceleration of 118.33 gal on the 6th floor in the E-W direction and a dominant period of 0.45 seconds in the E-W direction and 0.42 seconds in the N-S direction. EF-multistory recorded a maximum acceleration of 62.79 gal on the 6th floor in the E-W direction and a dominant period of 0.57 seconds in the E-W direction and 0.50 seconds in the N-S direction.

The dominant period in the E-W direction is normally larger than that in the N-S direction. The stiffness of IIS building in the E-W direction is smaller than that in the N-S direction.

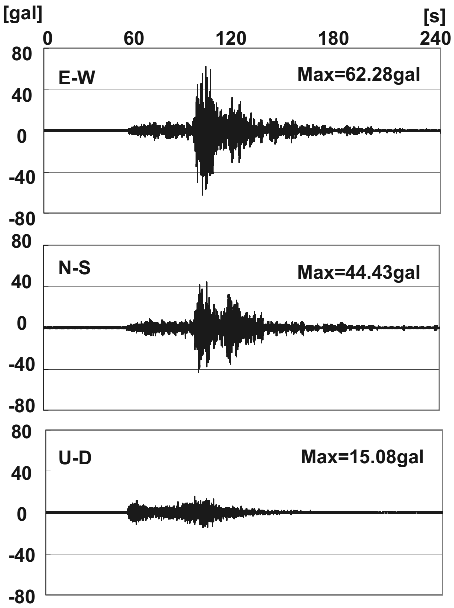

Figure 6. Earthquake record, 8th floor of F-building

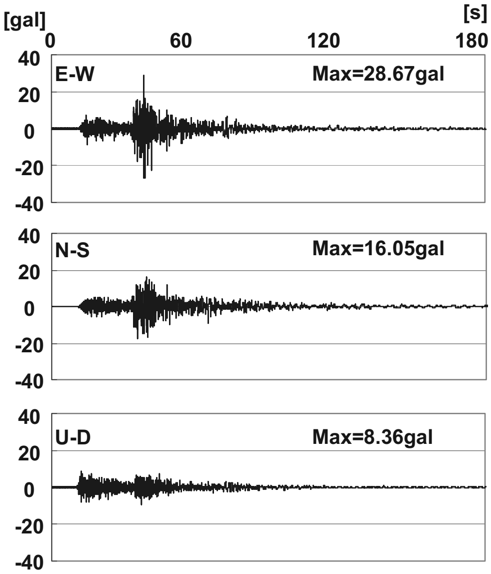

Figure 7. Earthquake record, ground surface

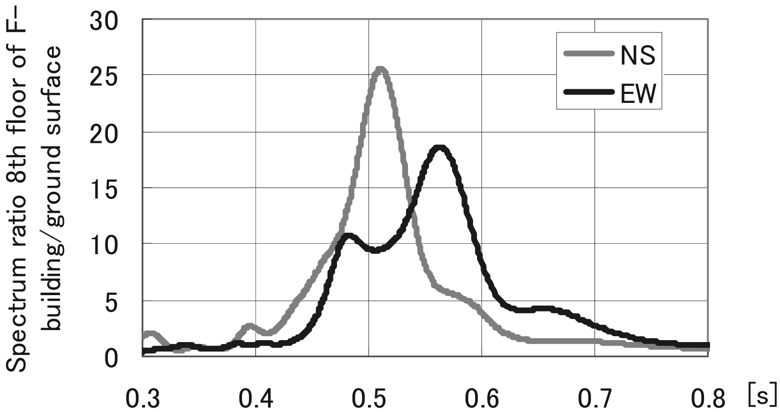

Figure 8. Spectrum ratio of F-8^{th} and ground surface

Table 1. Maximum acceleration and dominant period of IIS building

Building	story		Maximum acceleration (Gal)		dominant period (s)	
			EW	NS	EW	NS
BCD-multistory	8F	CwDw	93.75	36.17	0.54	0.42
	6F	Bw	45.78	23.32	0.45	0.42
	6F	CwDw	62.04	21.71	0.54	0.42
	4F	CwDw	35.23	16.10	0.54	0.42
	2F	CwDw	25.83	12.32	0.54	0.64
	B	Bw	20.58	11.47	0.34	0.64
BCD-building	6F	Be	89.54	31.92	0.44	0.42
	6F	CeDe	118.33	32.85	0.45	0.42
	4F	CeDe	64.51	18.05	0.45	0.42
	2F	CeDe	31.63	13.03	0.45	0.64
EF-multistory	8F	Fw	62.28	44.43	0.57	0.50
	6F	EwFw	62.79	27.86	0.57	0.50
	4F	EwFw	42.08	18.96	0.56	0.64
	2F	EwFw	26.20	14.59	0.56	0.64
	B	Fw	18.82	11.62	0.62	0.64
EF-building	6F	EeFe	66.35	48.89	0.45	0.45

Figure 9 shows the maximum displacement as recorded at each floor. Since the stiffness of the IIS building in the E-W direction can be estimated from the results of the dominant period, the displacement in the E-W direction becomes larger than that in the N-S direction. Assuming roughly 7 meters for story height, the story drift is very small and there is not enough displacement to initiate building collapse.

Figure 10 shows the displacement history observed at the upper floor and ground level. Regarding the motion characteristics of BCD-multistory (Cw/Dw 8F), 761.40 centimeters of accumulated displacement in the E-W direction and 622.65 centimeters in the N-S direction were calculated. This is because the stiffness in the N-S direction is larger than that in the E-W direction. The direction of input motion to BCD-multistory, basement (Bw B1) or bedrock (GL-18m), clearly show the anisotropic characteristics.

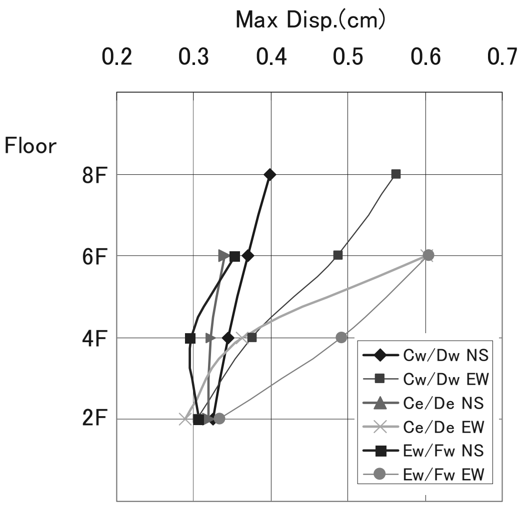

Figure 9. Maximum displacement of IIS building

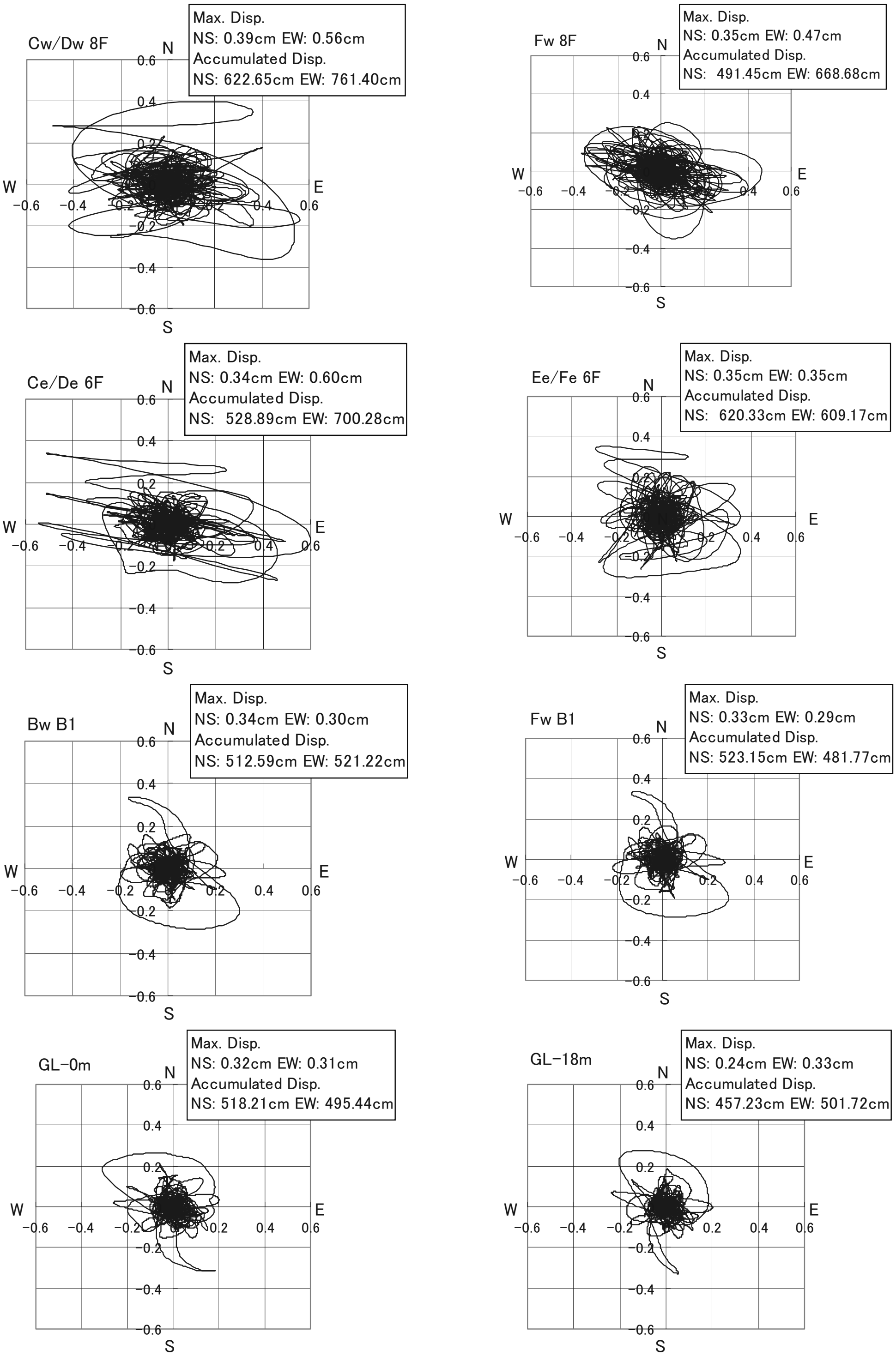

Figure 10. Displacement history

CONCLUSIONS

This paper discussed the results and observations taken by IT strong motion seismograph during the Suruga Bay earthquake.

The predicted damage which may be caused by the future Tokai Earthquake (M8) is estimated to be about 5,900 deaths, around 19,000 serious injuries and about 190,000 collapsed buildings. The earthquake which occurred on August 11th, 2009 provided an opportunity to develop countermeasures against the future Tokai earthquake, which has a 87% probability of occurring within 30 years, therefore, this earthquake is important when considering preparations for to the future Tokai Earthquake, even though the damage due to the Suruga Bay earthquake was small.

IT seismographs could observe this earthquake following the Chuetsu-oki earthquake in 2007. The observed data by this system is open to the public via web site and can be accessed outside (http://icus-eq.iis.u-tokyo.ac.jp/).

ACKNOWLEDGMENT

When the IIS building monitor system is operated, I am supported by Mr. Takamori Ito from Earthquake Research Institute, The University of Tokyo to install this system to IIS building.

REFERENCES

Japan Meteorological Agency (2009). "The report on Suruga bay earthquake on 11 August, 2009." (http://www.seisvol.kishou.go.jp/eq/2009_08_11_suruga-wan/index.html) (in Japanese)

The official residence emergency headquarters (2009). "The report on Suruga bay earthquake." (in Japanese)

The Cabinet Office (2009). " The damage due to Suruga bay earthquake." (in Japanese)

The Ministry of Land, Infrastructure and Transport (2009). "The influence of structure due to the seismic ground motion of Suruga bay earthquake" (in Japanese)

Takano, K., Ito, T., and Hara, T. (2004). "IT Kyoshin seismometer", Seismological Society of Japan, Autumn symposium (in Japanese)

Takano, K., and Ito, T. (2005). "IT Kyoshin seismometer for structures", Seismological Society of Japan, Autumn symposium (in Japanese)

Ohara, M., Ejima, J., and Meguro, K. (2008). "Observation Results in 2007 by IIS Building Monitoring System Using ITK Sensors", SEISANKENKYU, 60(3), 280-284. (in Japanese)