Journal of Japan Association for Earthquake Engineering, Vol.4, No.3 (Special Issue), 2004

SEISMIC OBSERVATION IN IRRIGATION DAM

Tamotsu FURUYA

Coordinator for disaster prevention research, National Institute for Rural Engineering, Tsukuba, Japan, tfuruya@nkk.affrc.go.jp

ABSTRACT: A large number of irrigation dams have been constructed in Japan. Strong earthquakes have often occurred and seismic observations in fill dams are very important for safety and countermeasures. Seismometers have been installed in 156 high irrigation dams since 1954 and seismic accelerations observed. Dynamic dam behavior is investigated by seismic observation records at the National Institute for Rural Engineering in cooperation with dam managers.

Key Words: Seismic observation, seismometer, irrigation, fill dam, dynamic behavior

INTRODUCTION

There are 3181 “high dams” higher than 15 m in Japan (1998). Of those dams, the number of fill dams is 2587 (1995), which accounts for 66% of the high dams of Japan. The number of irrigation dams higher than 15 m is 1707 (2000) and the number of fill dams for irrigation is 1517, which accounts for 87% of the irrigation dams higher than 15 m. Thus, fill dams are important facilities not only for irrigation water but also for conservation of water resources.

Japan is located in the Pacific earthquake belt and many strong earthquakes have often occurred. Earthquakes that have caused damage reach 436 throughout the known history of Japan (2001). High dams have been damaged partly by earthquakes that exceed M5.5, but such strong earthquakes have not caused catastrophic damage. Therefore, it is important to investigate the dynamic behavior of dams, especially fill dams, during earthquakes for safety.

HISTORY AND CURRENT STATE OF SEISIMIC OBSERVATION

Seismometers were installed first in the Sannoukai fill dam constructed in 1954 for seismic observations, and the number of dams with seismometers has increased, notably since 1978. Seismic accelerations have been observed in many dams and numerous seismic records have been accumulated. The number of dams with seismometers is 156 (2000), which accounts for only 9.1% of the total irrigation dams higher than 15 m. In such dams with seismometers installed, the necessity to check the dam embankment when an earthquake occurs is determined by the observed data at the dam site. Dam is checked when earthquake intensity exceeds 4. On the other hand, in other dams accounting for around 91%, the necessity to check the dam embankment when an earthquake occurs is determined by data from the Meteorological Observatory of the Japan Meteorological Agency nearest the dam site.

TYPES OF SEISMOMETER AND INSTALLED PLACES IN DAM

There are several types of seismometers such as the strong motion seismometer developed by the Strong Motion Accelerometer Committee (1952), the electromagnetic type seismometer and the servo velocity type seismometer that have been installed in dams. The servo velocity type seismometer is used in many dams constructed during the 1970's to the 1990's. Seismometers are commonly installed at the top of the embankment and in the inspection gallery or bedrock surface of the embankment. On the other hand, 10 seismometers have been installed in the Fukada dam (constructed in 1979) in Fukushima Prefecture, 8 seismometers in the Ohgaki dam (constructed in 1985, Table 1) as shown in Figs.1-3 in Fukushima Prefecture and 7 seismometers in the Sasagamine dam (constructed in 1983) in Niigata Prefecture.

Table 1 Location and dimension of Ogaki dam

Location	Murohara, Namie town, Futaba county, Fukushima Prefecture
	The Ukedo River Basin, The Ukedo River
	lat.37° 30.7' N, long. 140° 53.3' E
Foundation Geology	The Mesozoic Era, the Cretaceous period: biotitic Granite
	Rock grade: C_M～B
Dam type	Zoned rock-fill dam with central core
Elevation of Crest = 262.0 m, Dam Height = 84.5m	
Crest length = 262.0m, Crest Width = 10.0m, Volume of dam = 1,729,000m^3	
Crest length/ dam height (L/H) = 3.10	

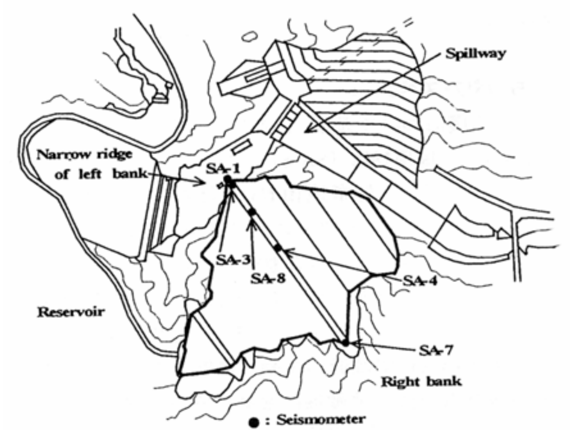

Fig.1 Topography and layout of Ohgaki dam and Seismometers

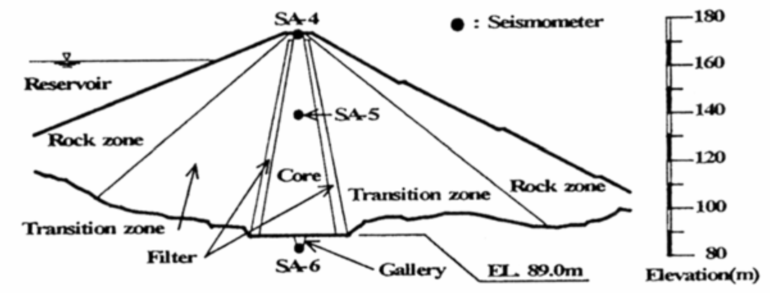

Fig.2 Typical cross section of Ohgaki dam and Seismometers

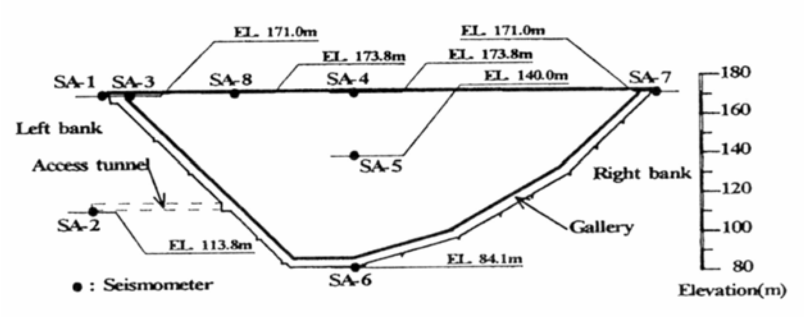

Fig.3 Longitudinal section of Ohgaki dam and Seismometers

MANAGER OF DAM AND SEISMOMETER

The managers of dams and seismometers are the Regional Agencies of the Ministry of Agriculture, Forestry and Fisheries (MAFF) or prefectures, cities, Land Improvement Associations, etc.

RESEARCH ON SEISMIC RECORD AND DYNAMIC BEHAVIOR OF FILL DAM

The dynamic behaviors of dams and countermeasures against earthquakes are investigated at the National Institute for Rural Engineering (NIRE) by seismic records in cooperation with dam managers for improvement of dam design and execution technique. Tanaka, et al. (1981) investigated the dynamic dam behaviors of earthquakes by the observed earthquake records of the Isshi, Ohkuragawa and the Fukada dams.

Masukawa, et al. (2002) also investigated the dynamic behaviors of 7 fill dams including the Fukada, Isshi, Minamishiio, Aratozawa, Nishonai, Ohgaki and the Wada dams by 29 acceleration wave records of 28 earthquakes with maximum acceleration measured at the bedrock of the fill dam exceeding 25 Gal. An outline of these 28 earthquakes and dams is shown in Table 2. The observed data are included in the report with CD.

Model tests with a three dimensional shaking table (4×6m) have been investigated and a simulation technique by dynamic response analysis developed in cooperation with the Faculty of Agriculture, Tokyo University, for the research on the dynamic behavior of fill dams and countermeasures against earthquakes. On the other hand, seismic data observed at fill dams were utilized not only to investigate the dynamic behavior of dams but also to examine the simulation technique by dynamic response analysis developed by the model tests as case histories of actual dam behavior during earthquakes.

CONCLUSIONS

Seismic accelerations have been observed in irrigation dams by MAFF, prefectures and Land Improvement Associations, etc. since the Sannoukai fill dam was constructed in 1954. The purposes of seismic observations are to investigate the dynamic behavior of dams during earthquakes and to obtain a guideline of emergency checks of dam embankments after an earthquake occurs. Seismic accelerations observed in dams were also utilized to develop a simulation technique by seismic response analysis. The three dimensional shaking table of NIRE was utilized in cooperation with MAFF and the Tokyo University for the fundamental research on this simulation technique. Safety of fill dams is very important in the irrigation sector when an earthquake occurs.

Table 2 Outline of observed earthquakes and dams

Geographical region name of epicenter	Origin Date	Origin Time	The north latitude	The east latitude	Depth (km)	Magnitude (Mj)	Recorded Dam	Epicentral distance (km)
Off Miyagi Prefecture	1978.6.12	17:14	38° 9'	142° 10'	40	7.4	Fukada	188.4
Off Fukushima Prefecture	1987.2.6	22:16	36° 58'	141° 54'	35	6.7	Ogaki	108.3
Off Fukushima Prefecture	1987.4.7	9:40	37° 18'	141° 52'	44	6.6	Ogaki	89.8
Off Fukushima Prefecture	1987.4.23	5:13	37° 5'	141° 38'	47	6.5	Ogaki	80.6
Central Mie Prefecture	1989.2.19	13:58	34° 37'	136° 28'	45	5.3	Isshi	4.3
South western Ibaraki Prefecture	1992.4.14	12:3	36° 11'	139° 50'	62	4.9	Minamishiio	22
South western Ibaraki Prefecture	1992.4.23	1:21	36° 6'	139° 53'	58	4.3	Minamishiio	22.3
Central Ibaraki Prefecture	1992.5.11	19:7	36° 32'	140° 32'	56	5.6	Minamishiio	53.7
South western Ibaraki Prefecture	1992.8.27	13:9	36° 3'	139° 59'	57	4.7	Minamishiio	21.4
Nouthern Ibaraki Prefecture	1992.9.14	11:46	36° 26'	140° 40'	55	4	Minamishiio	58.3
Off Kushiro	1993.1.15	20:6	42° 55'	144° 21'	101	7.8	Wada	367.5
South western Ibaraki Prefecture	1993.5.16	22:18	36° 9'	140° 3'	58	3.7	Minamishiio	8.6
South western Ibaraki Prefecture	1993.5.21	11:36	36° 3'	139° 54'	61	5.3	Minamishiio	26
East off Ibaraki Prefecture	1993.9.18	11:18	36° 11'	140° 53'	35	5	Minamishiio	73.8
Southern Ibaraki Prefecture	1993.11.1	21:22	36° 6'	140° 14'	82	4.6	Minamishiio	20.5
South western Ibaraki Prefecture	1994.1.23	15:43	36° 19'	140° 5'	77	4.4	Minamishiio	9.9
East off Ibaraki Prefecture	1994.3.9	19:2	36° 25'	141° 7'	40	4.9	Minamishiio	97
South western Ibaraki Prefecture	1994.5.31	4:20	36° 14'	140° 1'	58	3.8	Minamishiio	5.3
Nouthern Ibaraki Prefecture	1994.8.30	1:55	36° 27'	140° 42'	50	4.3	Minamishiio	62.2
Nouthern Ibaraki Prefecture	1994.9.6	19:0	36° 29'	140° 35'	54	4.2	Minamishiio	54.1
East off Hokkaido	1994.10.4	22:22	43° 22'	140° 41'	28	8.1	Wada	621.7
South western Ibaraki Prefecture	1994.11.4	19:6	36° 3'	139° 55'	56	4.3	Minamishiio	24.4
Far off Sanriku	1994.12.28	21:19	40° 26'	143° 45'	0	7.5	Wada Nishonai	227 256.2
South western Ibaraki Prefecture	1995.1.7	21:34	36° 18'	139° 59'	71	5.4	Minamishiio	10.6
South western Ibaraki Prefecture	1995.3.23	7:24	36° 6'	140° 1'	56	4.9	Minamishiio	16
Nouthern Miyagi Prefecture	1996.8.11	3:12	38° 54'	140° 38'	9	5.9	Aratozawa	19.5
Nouthern Miyagi Prefecture	1996.8.11	8:10	38° 52'	140° 41'	10	5.7	Aratozawa	16.2
Nouthern Miyagi Prefecture	1996.8.11	15:1	38° 51'	140° 41'	10	4.4	Aratozawa	15.4

ACKNOWLEDGMENT

A risk management system is prepared so the dam managers can request MAFF and NIRE dispatch of experts to strictly check the safety of dams if needed, when an earthquake occurs.

REFERENCES

Tanaka, T., Yasunaka, M., Kawamoto, O., Nakano, R. (1981): The record of earthquake observation and the dynamic behaviors of earth and rock-fill dams (In Japanese). Technical report of the National Research Institute of Agricultural Engineering, C21, p.1-57

Masukawa, S., Kohgo, Y., Asano, I., Hayashida, Y. (2002): Seismic behaviors of fill dams by observing earthquake records (In Japanese). Bulletin of the National Institute for Rural Engineering, No.41, p.19- 58

(Submitted: March 31, 2004)
(Accepted: June18, 2004)