



International Symposium
Qualification of dynamic analyses of dams and their equipments
and of probabilistic assessment seismic hazard in Europe
31th August – 2nd September 2016 – Saint-Malo

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Session 5: Qualification of seismic analyses of concrete dams

CHARACTERISTICS OF PREDOMINANT FREQUENCY OF AN EXISTING ARCH DAM



SUMMARY

1. INTRODUCTION

MOTIVATION
IKEHARA DAM
EARTHQUAKE MONITORING

2. DYNAMIC BEHAVIOR

ACCELERATION RESPONSE
DOMINANT FREQUENCY
MICROTREMOR MEASUREMENT
DYNAMIC SIMULATION

3. CONCLUSIONS

MOTIVATION

- A dynamic behavior of an existing arch dam of 111 m high during earthquakes are examined using the **earthquake monitoring data**,
 - To identify the dam behavior in a sound condition
 - To elaborate the management criteria for detecting abnormalities in the dam in terms of deviation from the sound behavior
 - To evaluate the current dynamic properties of the dam for safety assessment of the dam

IKEHARA DAM



Concrete arch dam for hydropower
(Completed in 1964)

Dam height : 111 m, Crest length : 460 m

Characteristics of predominant frequency
of an existing arch dam | 2016

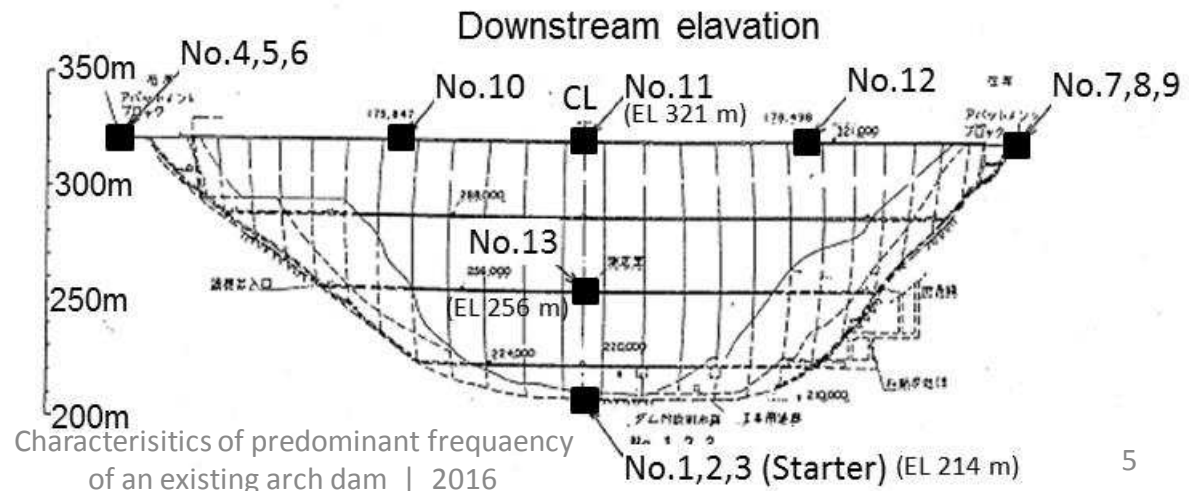
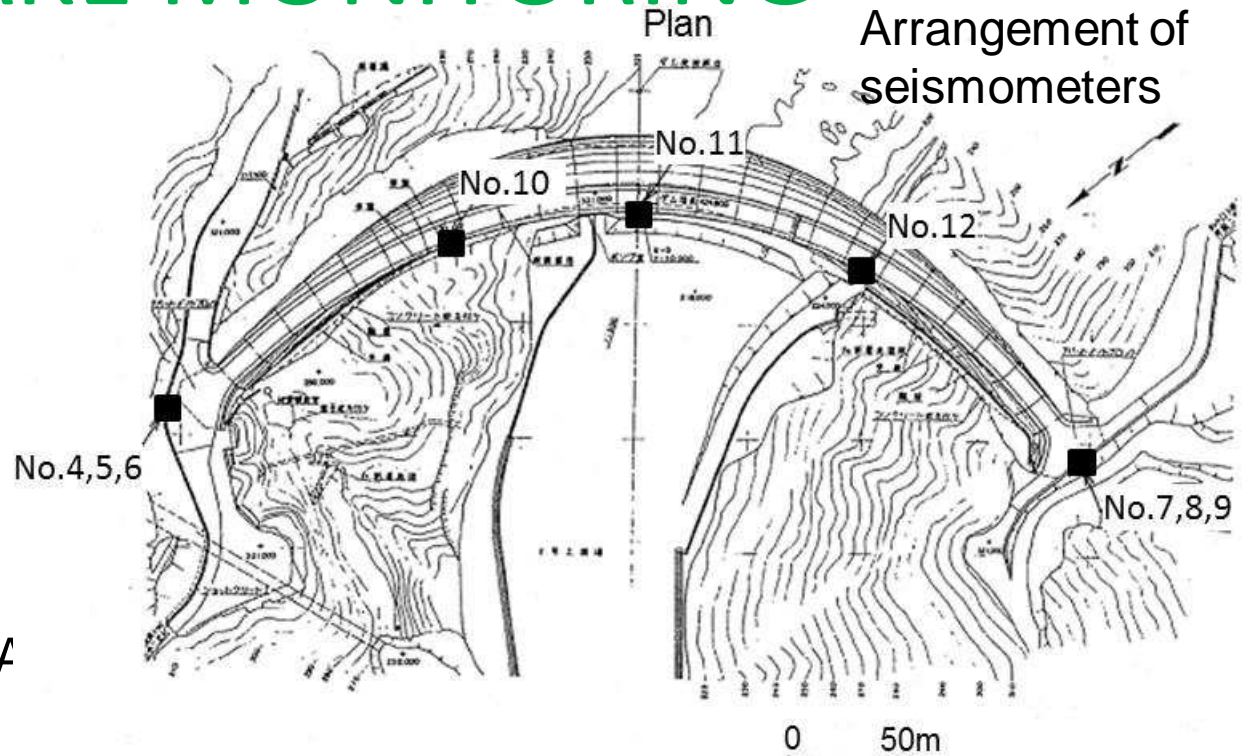
Location

EARTHQUAKE MONITORING



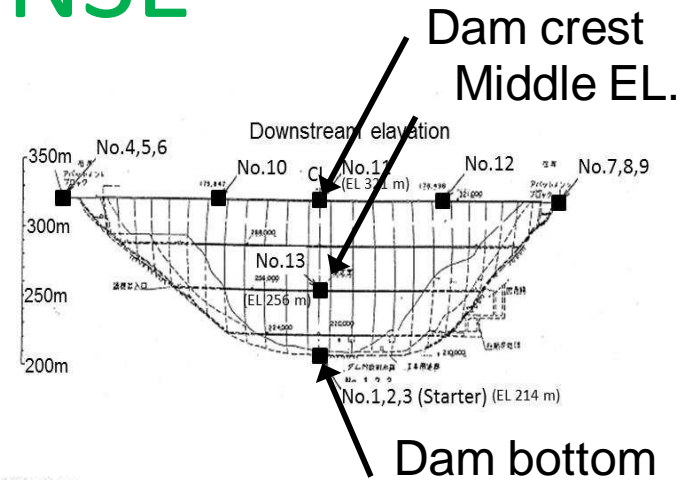
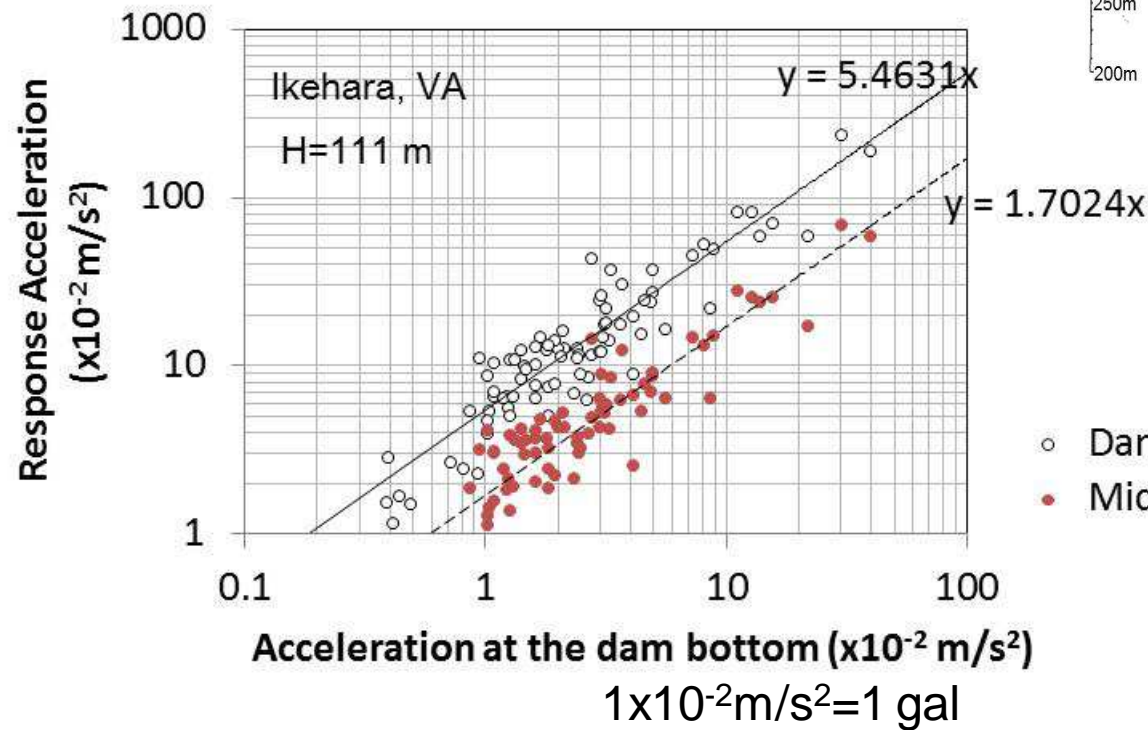
Seismometer(JEP-4)

- (1) About **90 events** have been monitored since 1987.
- (2) The max. acceleration was recorded at 30 gal and **240 gal** at the foundation and the dam crest, respectively.



Characteristics of predominant frequency of an existing arch dam | 2016

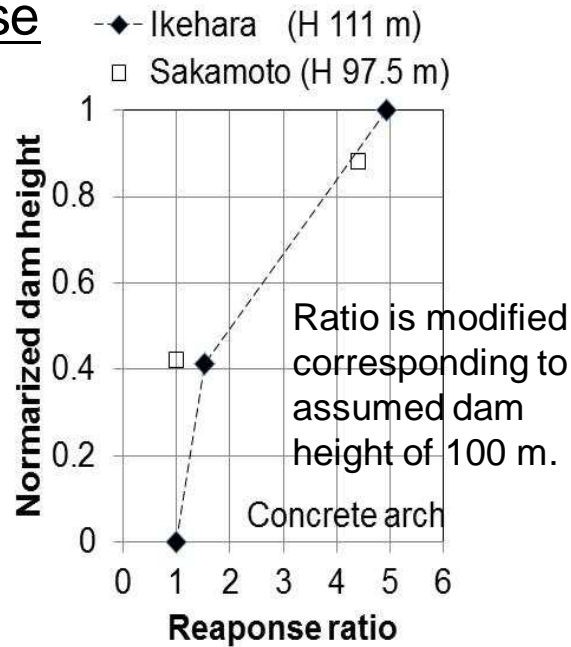
ACCELERATION RESPONSE



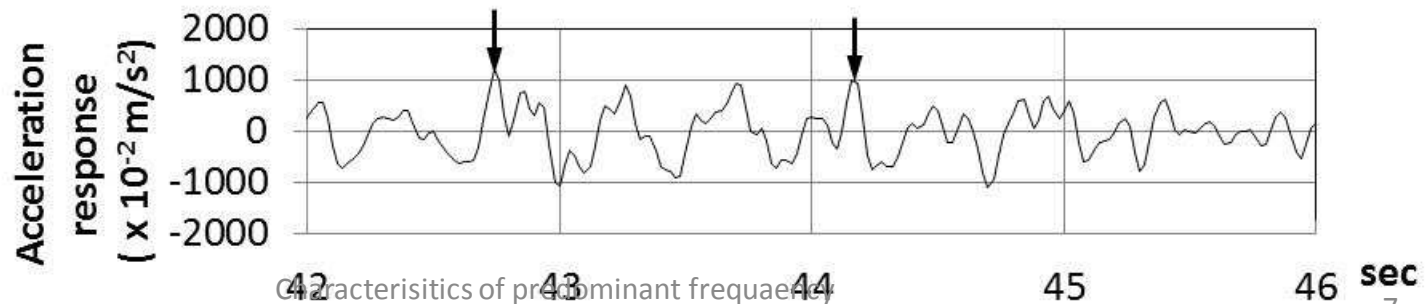
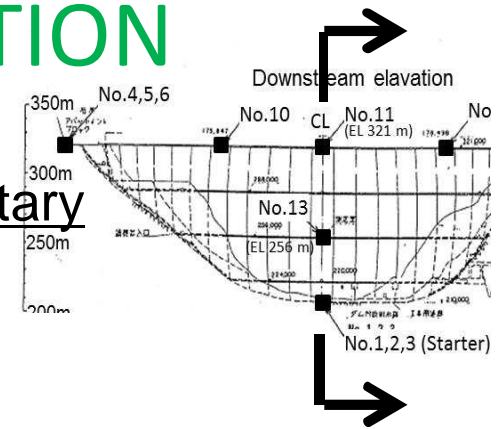
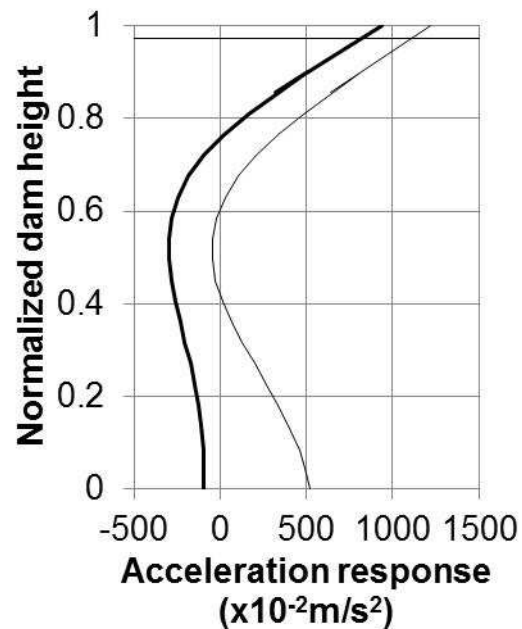
- Dam crest, Center
- Middle elevation

RESPONSE PROFILE OF ACCELERATION

Monitored profile of the max. response

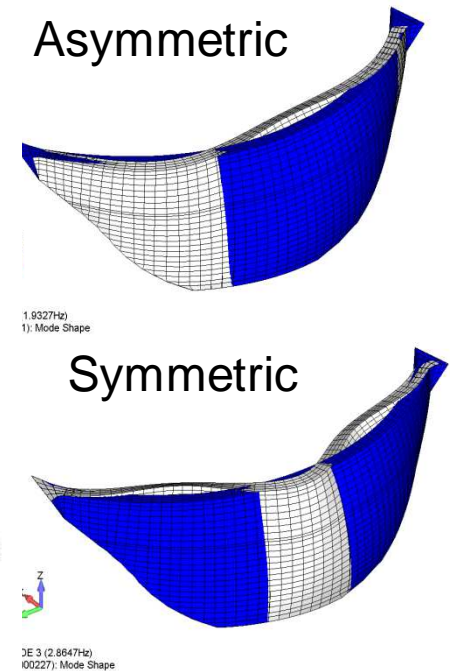
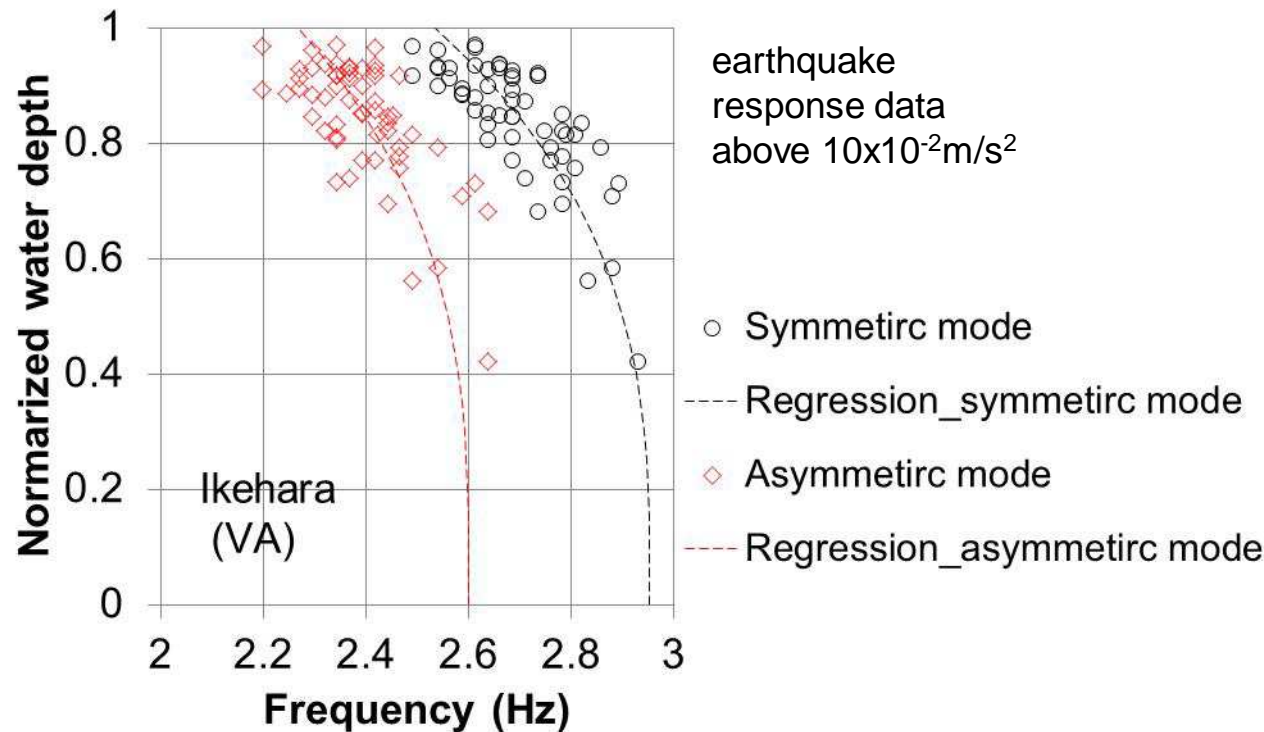


Simulated momentary profile



Characteristics of predominant frequencies of an existing arch dam | 2016

DOMINANT FREQUENCY OF AN ARCH DAM

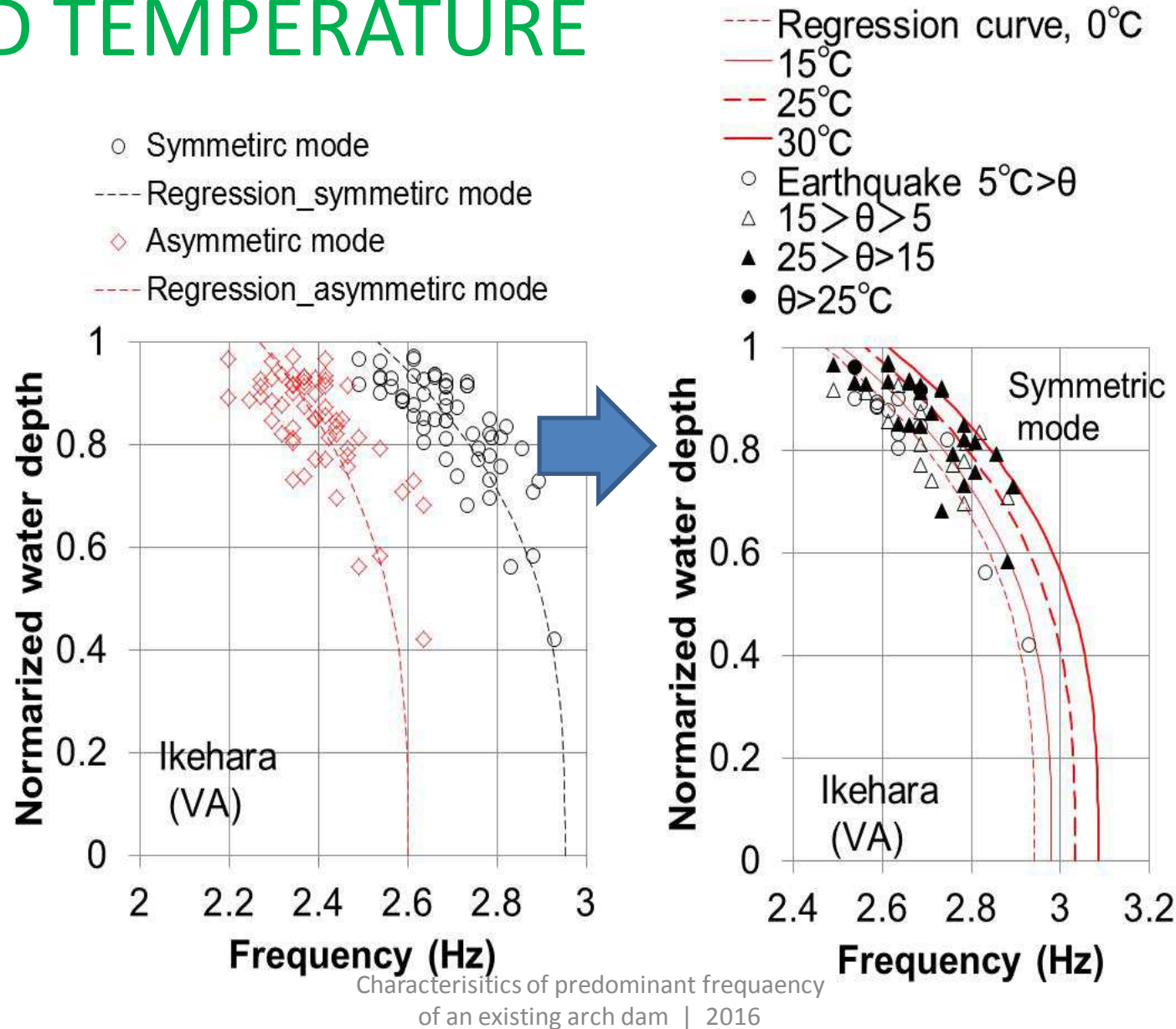


$$f_1(h, \theta) = c_0 + c_1(h/H)^\beta + \frac{c_2}{\sqrt{\theta^* - \theta}} + e$$

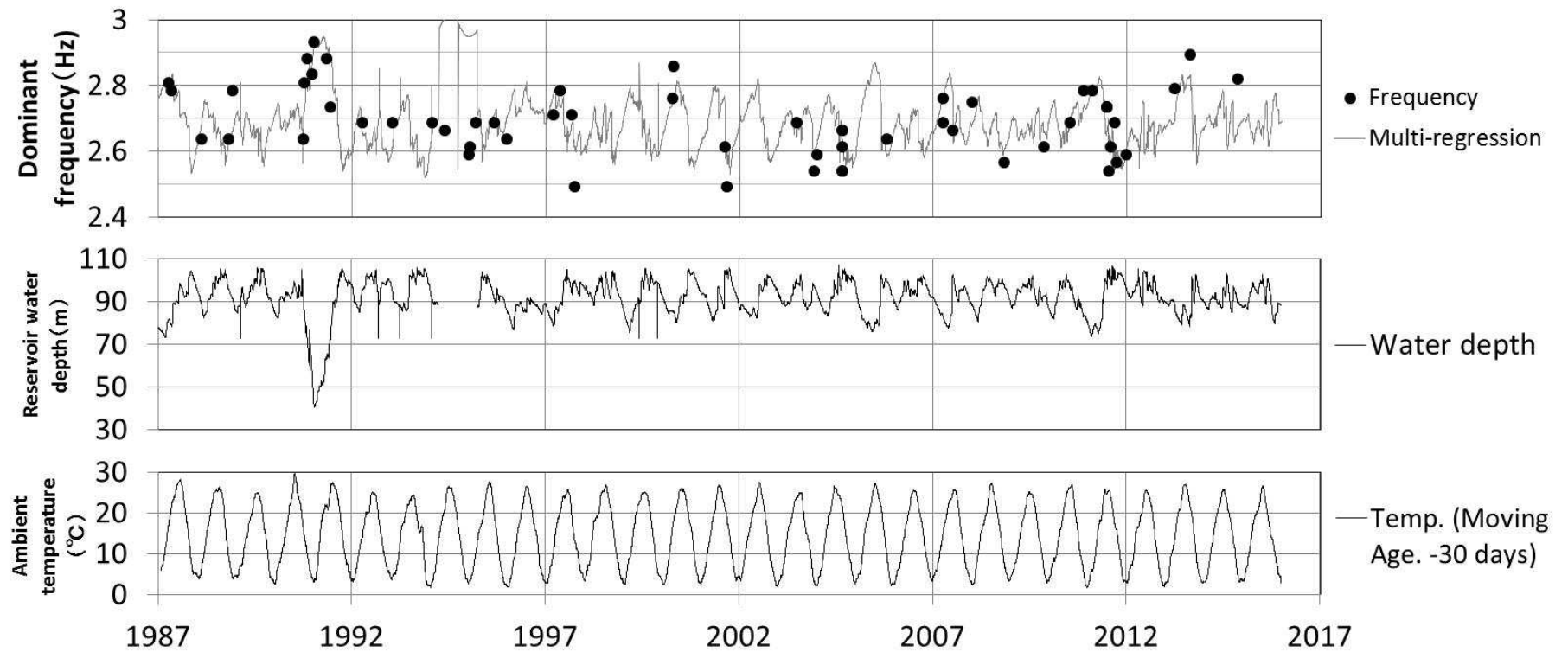
After Kondo et. al. 2015

Where, $f_1(h, \theta)$: predominant frequency, h : water depth of the reservoir, H : full depth of the reservoir, β : Parameter(=3.0), θ : ambient temperature, θ^* : ambient temperature corresponding to zero opening of the transverse joint (40°C is adopted.), c_0, c_1, c_2 : constant, e : residual

DEPENDENCY ON WATER DEPTH AND TEMPERATURE



ESTIMATION OF DOMINANT FREQUENCY USING REGRESSION FORMULA



MICROTREMOR MEASUREMENT

Sarvo Velocity-meter



Bottom gallery



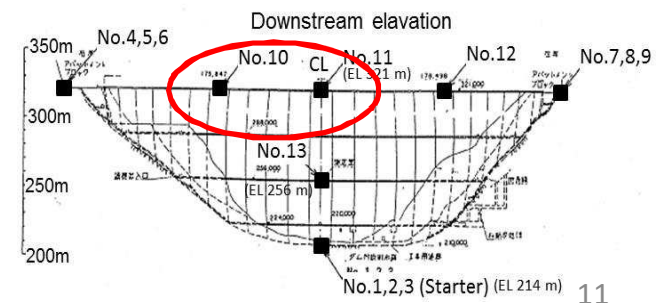
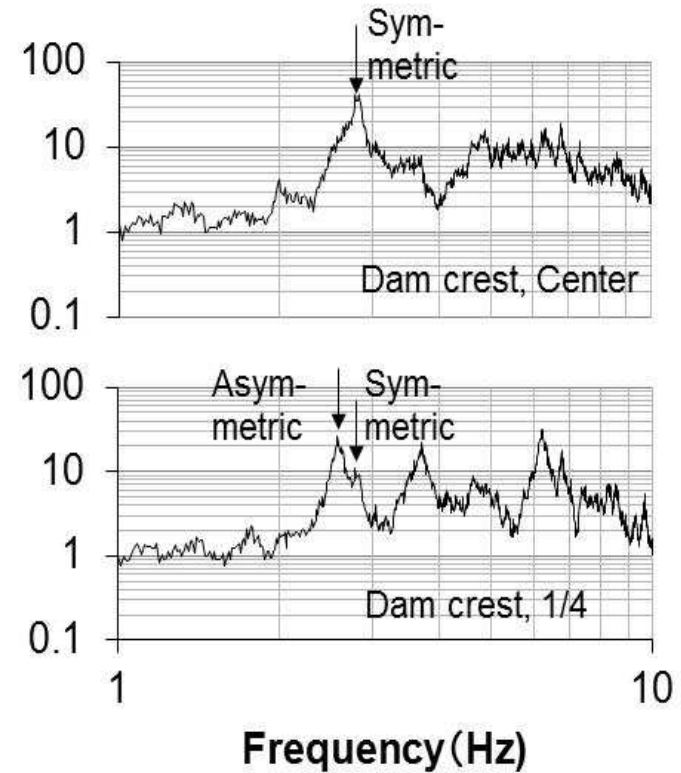
Dam crest

High precision accelerometer

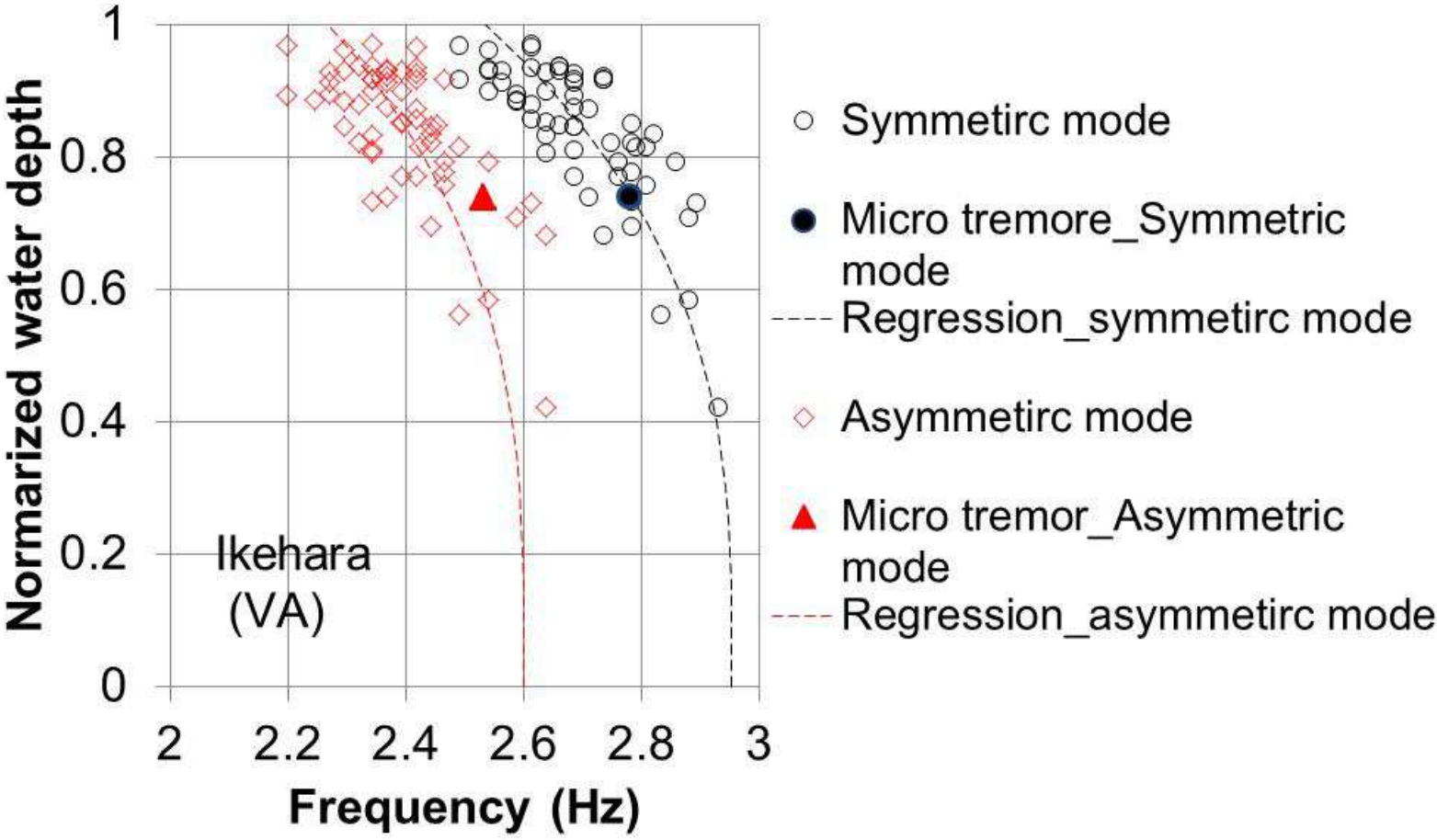


Bottom gallery

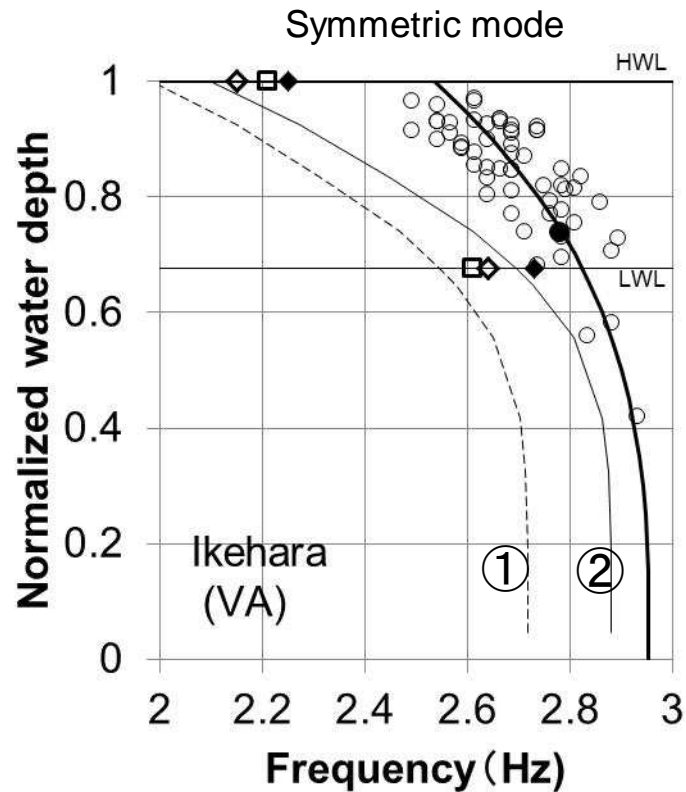
Transfer function



COMPARISON BETWEEN MICROTREMOR MEASUREMENT AND EARTHQUAKE MONITORING

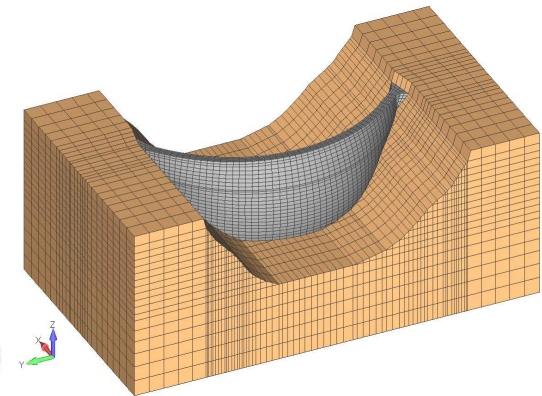


DYNAMIC SIMULATION

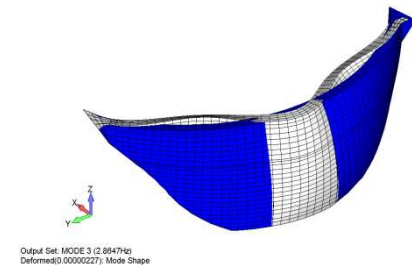


- Earthquake monitoring
- Micro tremore
- Regression curve
- - - Eigen frequency with ①
- Eigen frequency with ②
- D.A. with ① & random wave
- ◇ D.A. with ① & Pulse wave
- ◆ D.A. with ② & Pulse wave
- HWL
- LWL

D.A. : Dynamic analysis
 Dam elasticity
 ① : $E=35000\text{MN/m}^2$
 ② : $E=40000\text{MN/m}^2$



Numerical model



Symmetric mode

Elastic modulus of the dam	35000 MN/m ²	40000 MN/m ²
Eigen value simulation	Done	Done
Earthquake wave response (Dam-reservoir interaction)	Done	
Pulse wave response (Added mass)	Done	Done

Material test
 $E_{static}=44000\text{MN/m}^2$
 for extracted specimen
 after 50 years

CONCLUSIONS (1)

- The dynamic characteristics of the existing arch dam is clarified.
 - Acceleration response is linear to the magnitude of the earthquake excitation.
 - Dominant frequency depends significantly on the reservoir water depth and the ambient temperature.
 - The dominant frequency is well formulated in terms of influential parameters.
- These characteristics are beneficial to the soundness management of the dam.

CONCLUSIONS (2)

- It is considered that the dominant frequency attribute to the dynamic properties of the dam.
- Therefore, the current properties can be evaluated by the dynamic simulation of which results coincide to the monitored dominant frequency.
- Such examination is essential to the safety assessment of dams during large earthquakes.
- Microtremor measurement is effective in these examination where no earthquake monitoring data is available.

THANK YOU FOR
YOUR ATTENTION

