Short Report_ver2: Evaluation of Constant-Ductility Response Spectra and Energy Equivalent Velocity Spectra Using Observed Earthquake Records in the Seismic Event of "2011 Tohoku-Pacific Earthquake"

1. Introduction

In this report, constant-ductility response spectra and energy equivalent velocity spectra (both absolute and relative) are computed and added to the last report by using observed records in Tohoku and Kanto regions in the seismic event of Tohoku-Pacific Earthquake having occurred at 14:46 March 11 2011. The data recorded by NIED K-NET were used in this report.

2. Data Used

| No. | Name | Observed Time | Long. | Lati. | Alti. | Epicent. | Max. Acc. | Period of Soil | Soil Type (Railway) | Soil Type (Highway) | Max. Acc. Resp. Spec. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| IWA012 | Kitakami | March 11-14:46:52 | 39.3209N | 141.1378E | 64.00m | 212km | 627.7gal | 0.25s | G3 | II | 28.5m/s2(0.31s)-NS |
| IWA018 | Morioka | March 11-14:46:58 | 39.6953N | 141.1478E | 125.00m | 242km | 259.5gal | 0.17s | G2 | I | 10.4m/s2(0.23s)-EW |
| MYG004 | Tsukidate | March 11-14:46:51 | 38.7292N | 141.0217E | 40.00m | 183km | 2933.2gal | 0.13s | G0 | I | 129.5m/s2(0.24s)-NS |
| MYG012 | Shiogama | March 11-14:46:50 | 38.3175N | 141.0193E | 1.73m | 169km | 2018.9gal | 0.17s | G2 | I | 31.65m/s2(0.37s)-EW |
| MYG013 | Sendai | March 11-14:46:50 | 38.2663N | 140.9293E | 5.00m | 175km | 1807.8gal | 0.26s | G3 | II | 26.84m/s2(0.61s)-NS |
| MYG015 | Iwanuma | March 11-14:46:49 | 38.1049N | 140.8699E | 3.00m | 179km | 433.6gal | 0.42s | G3 | II | 17.41m/s2(0.57s)-NS |
| FKS001 | Souma | March 11-14:46:50 | 37.7949N | 140.9196E | 9.00m | 176km | 682.8gal | 0.26s | G3 | II | 18.21m/s2(0.73s)-EW |
| FKS002 | Yanagawa | March 11-14:46:55 | 37.8449N | 140.6013E | 42.00m | 203km | 629.3gal | 0.12s | G2 | I | 26.33m/s2(0.13s)-NS |
| FKS003 | Fukushima | March 11-14:46:58 | 37.7613N | 140.4799E | 64.00m | 215km | 329.1gal | 0.13s | G0 | I | 9.82m/s2(0.13s)-NS |
| FKS019 | Nihonmatsu | March 11-14:46:57 | 37.6030N | 140.4368E | 235.00m | 221km | 461.4gal | 0.21s | G2 | I | 22.12m/s2(0.35s)-NS |
| TCG001 | Kuroiso | March 11-14:47:10 | 36.9417N | 140.0828E | 254.80m | 275km | 485.7gal | 0.11s | G2 | I | 11.84m/s2(0.41s)-NS |
| TCG014 | Moteghi | March 11-14:47:09 | 36.5450N | 140.1742E | 130.00m | 291km | 1291.1gal | 0.17s | G2 | I | 51.37m/s2(0.40s)-EW |
| IBR003 | Hitachi | March 11-14:47:05 | 36.5915N | 140.6453E | 57.50m | 254km | 1845.2gal | 0.33s | G3 | II | 75.09m/s2(0.32s)-NS |

＊The maximum acceleration shown above was obtained from the data where the mean value of the amplitude was subtracted from the original record.

3. Conditions of Calculations

1. Clough model is assumed as the inelasticity of structures
2. The ratio of the tangent stiffness to the initial stiffness is assumed to be 0.1
3. Damping constant 0.05
4. Newmark's Method ($\beta$=1/6)
5. Time interval 0.01

4. Definition of Input Energy

・Absolute Input Energy

$$E_I = Max\left(\int_0^{t_a} m(\ddot{u}+\ddot{u}_g)\dot{u}_g\,dt\right)$$

・Relative Input Energy

$$E_I = Max\left(\int_0^{t_a} m\ddot{u}_g \dot{u} dt\right)$$

・Energy Equivalent Velocity (Unit mass was used here)

$$V_e = \sqrt{2E_I / m}$$

4．Results

Results are shown in the following part. (saity@mail.saiama-u.ac.jp)

Date March 29 2011
Graduate School of Science and Engineering
Saitama University, Japan
Masato Saitoh

<Information>

Seismograph: K-NET02

Recorded Point: IWA012

Name: Kita-Kami

Observed Time: March 11-14:46:52

Longitude 39.3209N Latitude 141.1378E Altitude 64.00m

Epicentral Distance 212km

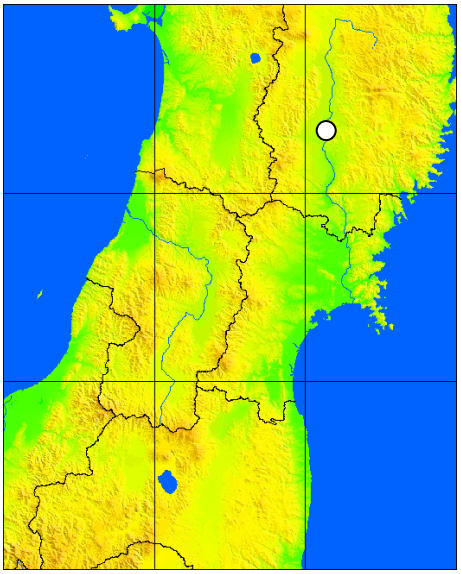
Max. ACC. 627.7gal

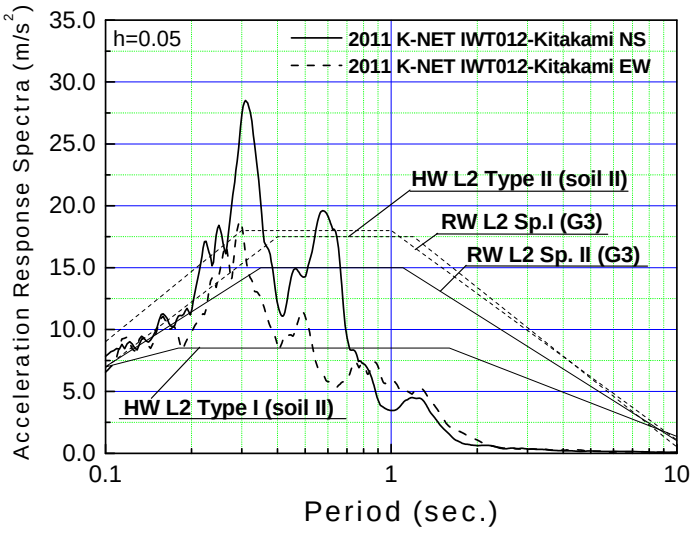
Period of Soil at Site about 0.25s

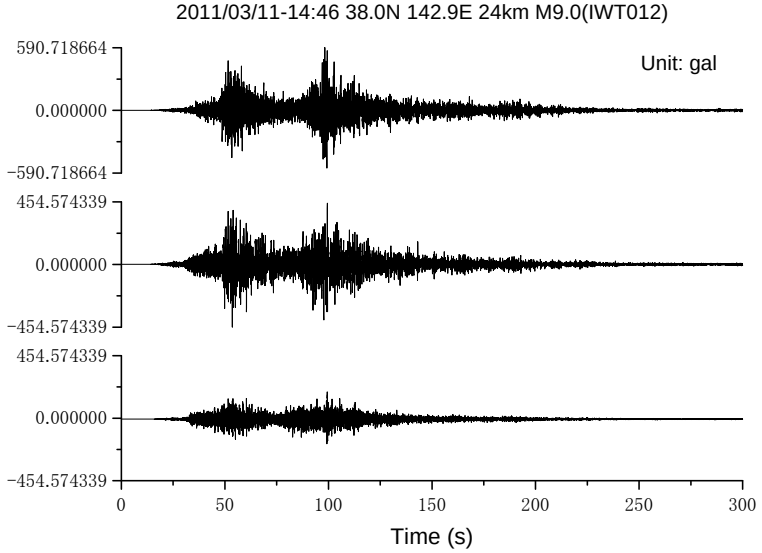
Soil Type(Railway) G3 (Highway) Type II

Acc. Response Spec. Max. 28.5m/s² (at 0.31s) (5%damping)

Address 214-1 Toribami, Futago-Chyo Kita-Kami City, Iwate Prefecture





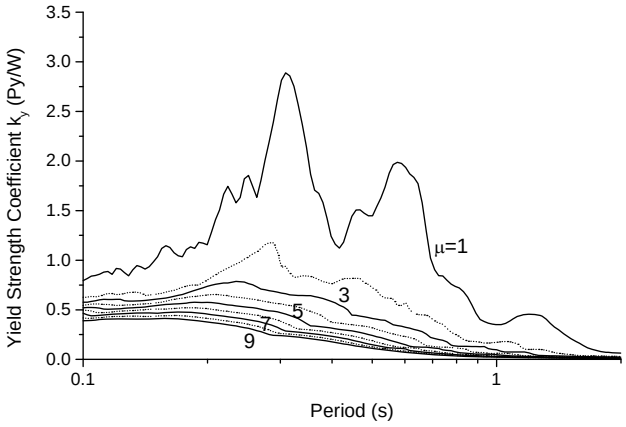



Fig.1 Constant-Ductility Response Spectrum

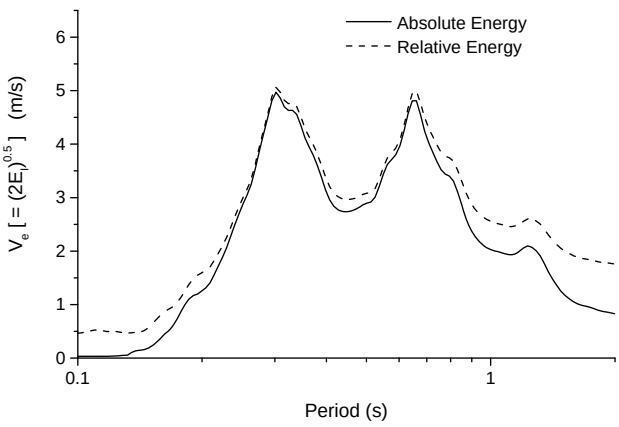



Fig.2 Linear Energy Equivalent Velocity (EEV)

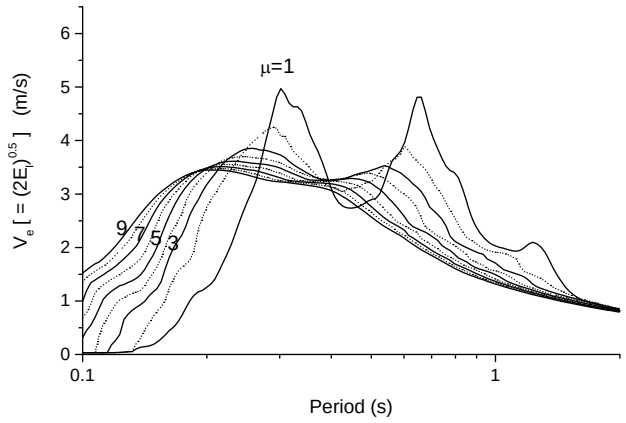



Fig.3 Absolute-EEV with Ductility Factors

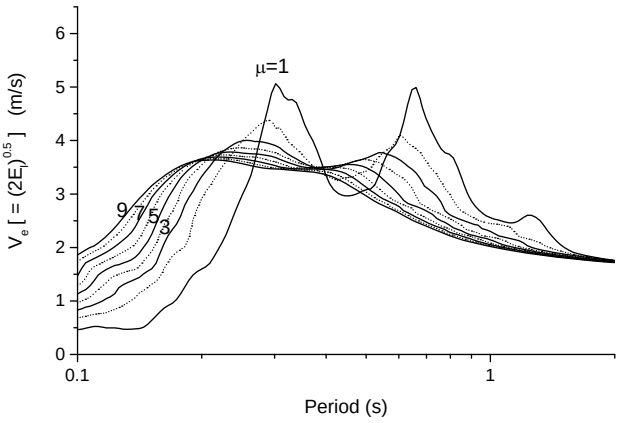



Fig.4 Relative-EEV with Ductility Factors

Acknowledgements:
We used data from NIED K-NET.
Saitama Univ. M. Saitoh

<Information>

Seismograph: K-NET02

Recorded Point: IWA018

Name: Morioka

Observed Time: March 11-14:46:58

Longitude 39.6953N Latitude 141.1478E Altitude 125.00m

Epicentral Distance 242km

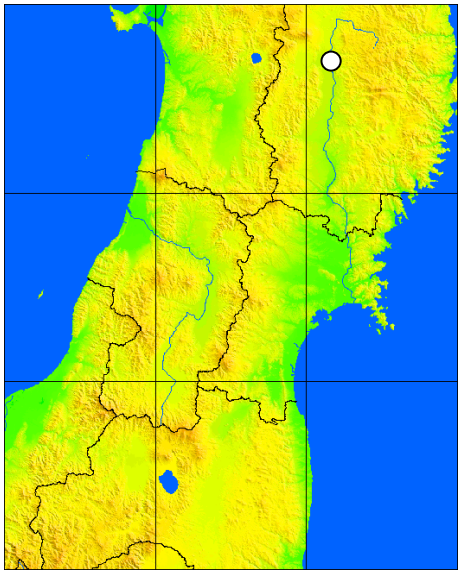
Max. ACC. 259.5gal

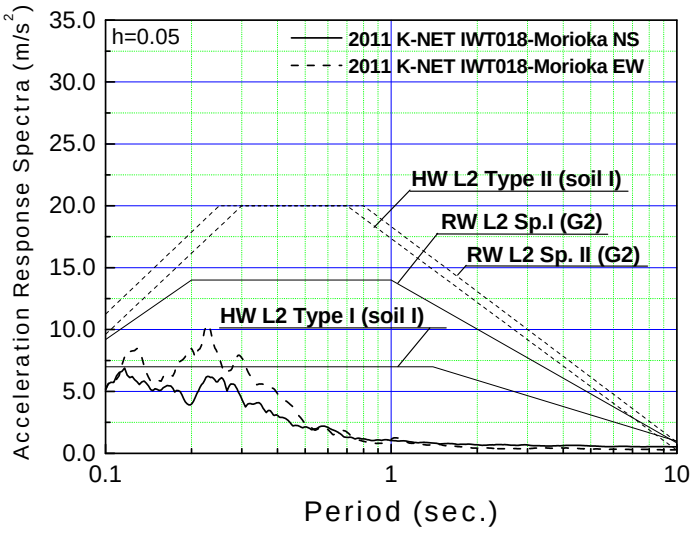
Period of Soil at Site about 0.169s

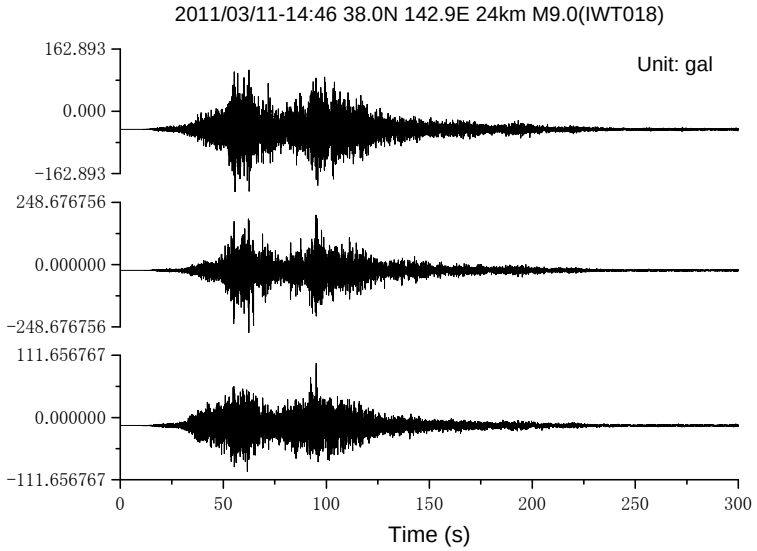
Soil Type(Railway) G2 (Highway) Type I

Acc. Response Spec. Max. 10.4m/s² (at 0.23s) (5%damping)

Address 77-9 141-3 Baba-Chyo Morioka City, Iwate Prefecture





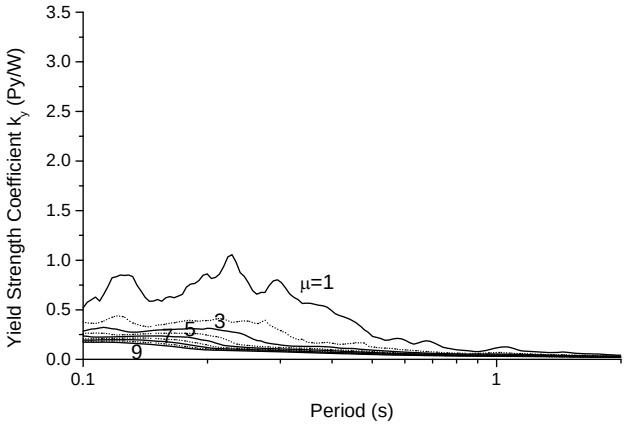



Fig.1 Constant-Ductility Response Spectrum

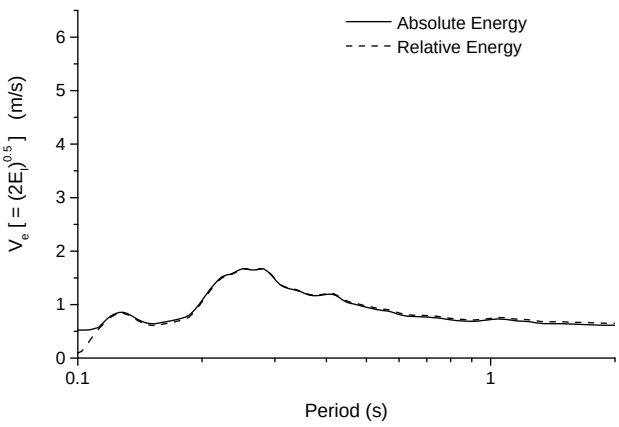



Fig.2 Linear Energy Equivalent Velocity (EEV)

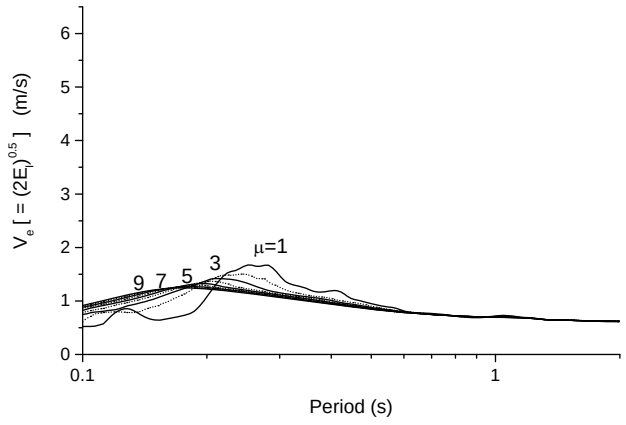



Fig.3 Absolute-EEV with Ductility Factors

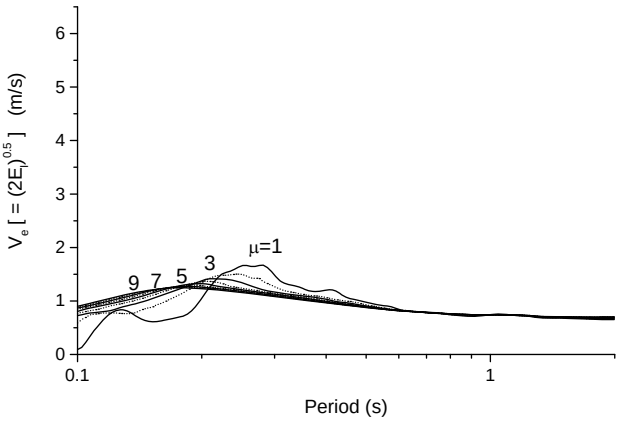



Fig.4 Relative-EEV with Ductility Factors

Acknowledgements:
We used data from NIED K-NET.
Saitama Univ. M. Saitoh

<Information>

Seismograph: K-NET02

Recorded Point: MYG004

Name: Tsukidate

Observed Time: March 11-14:46:51

Longitude 38.7292N Latitude 141.0217E Altitude 40.00m

Epicentral Distance 183km

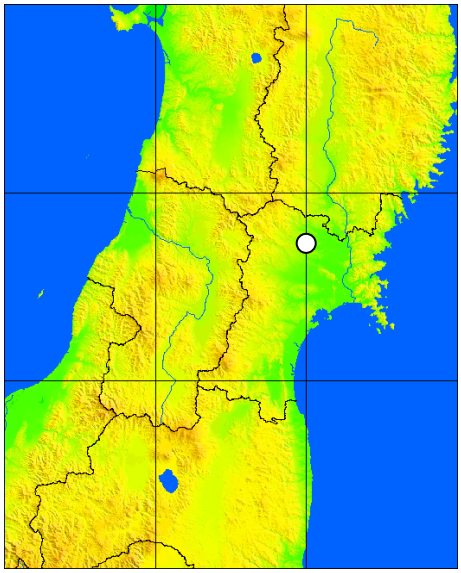
Max. ACC. 2933.2gal

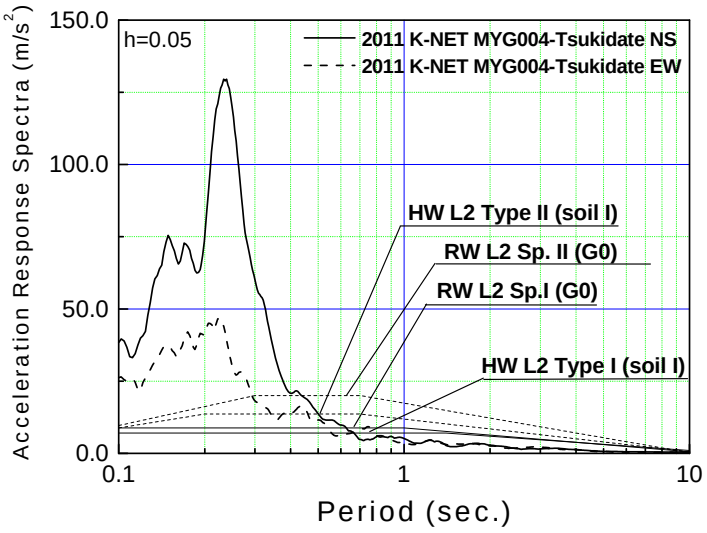
Period of Soil at Site about 0.134s

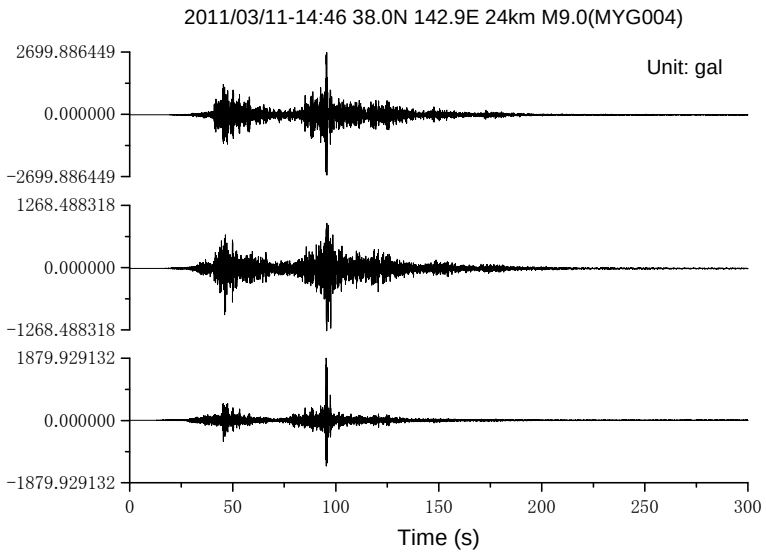
Soil Type(Railway) G0 (Highway) Type I

Acc. Response Spec. Max. 129.5m/s2 (at 0.24s) (5%damping)

Address 2-15 Tsukidate-Takada, Kurihara City, Miyaghi Prefecture





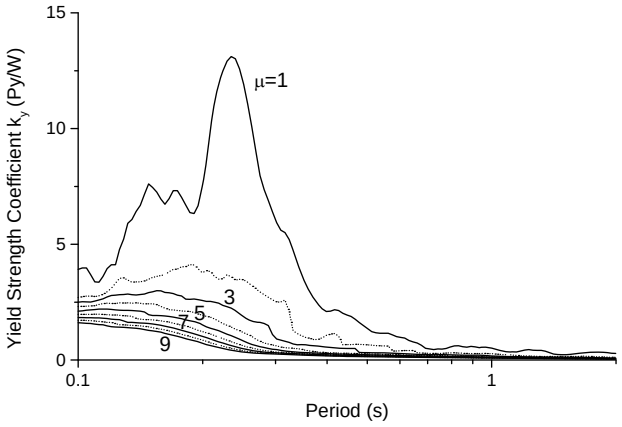



Fig.1 Constant-Ductility Response Spectrum

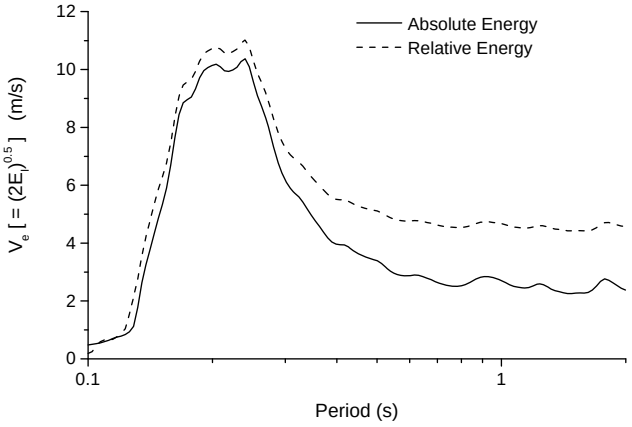



Fig.2 Linear Energy Equivalent Velocity (EEV)

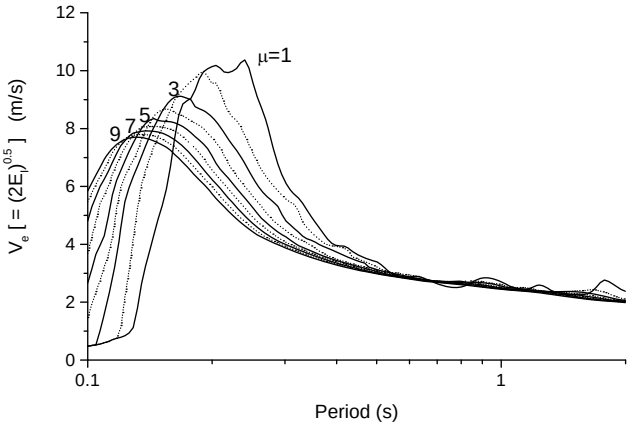



Fig.3 Absolute-EEV with Ductility Factors

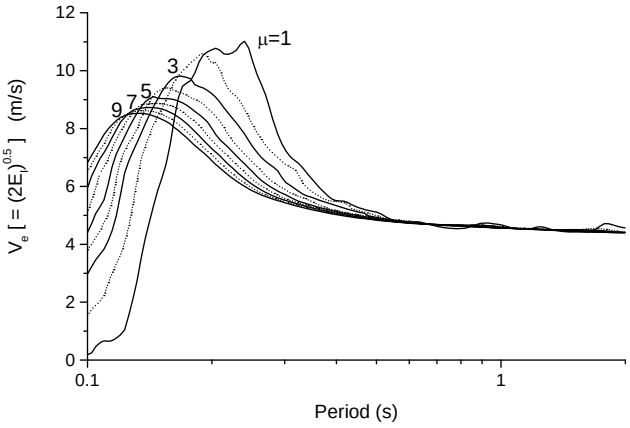



Fig.4 Relative-EEV with Ductility Factors

Acknowledgements:
We used data from NIED K-NET.
Saitama Univ. M. Saitoh

<Information>

Seismograph: K-NET02

Recorded Point: MYG012

Name: Shiogama

Observed Time: March 11-14:46:50

Longitude 38.3175N Latitude 141.0193E Altitude 1.73m

Epicentral Distance 169km

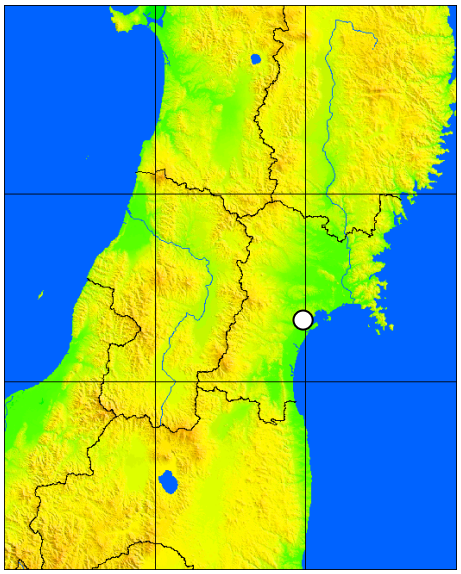
Max. ACC. 2018.9gal

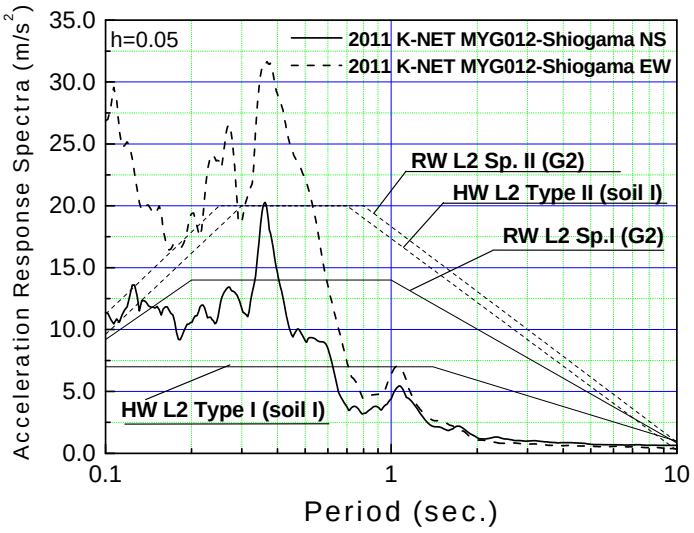
Period of Soil at Site about 0.17s

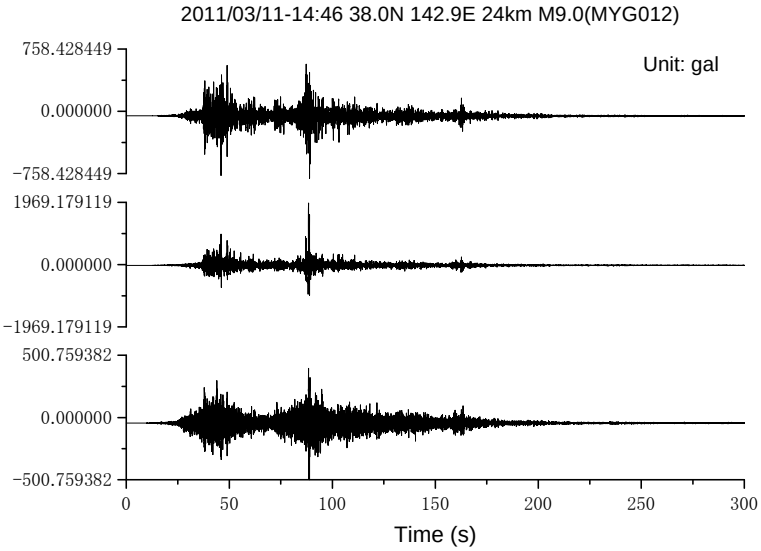
Soil Type(Railway) G2 (Highway) Type I

Acc. Response Spec. Max. 31.65m/s2(at 0.37s) (5%damping)

Address 1-1, Asahi-Chyo, Shiogama City Miyaghi Prefecture





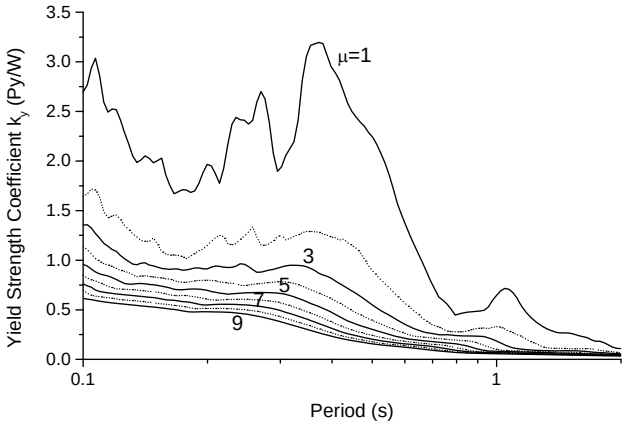



Fig.1 Constant-Ductility Response Spectrum

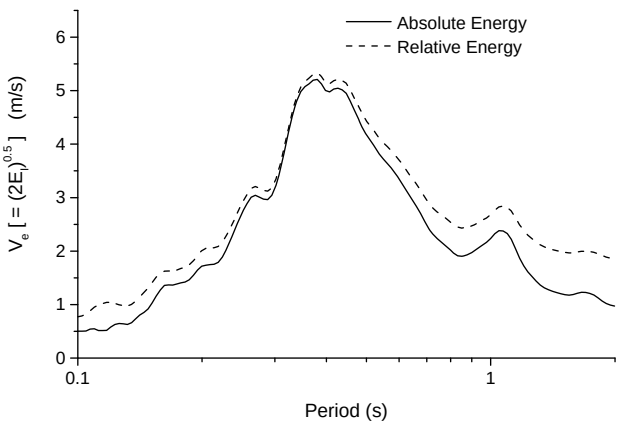



Fig.2 Linear Energy Equivalent Velocity (EEV)

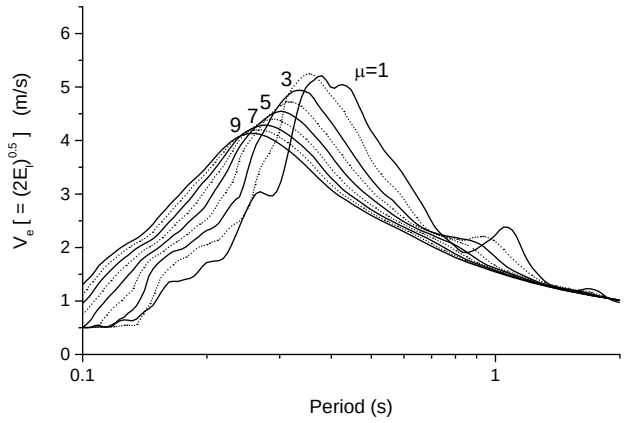



Fig.3 Absolute-EEV with Ductility Factors

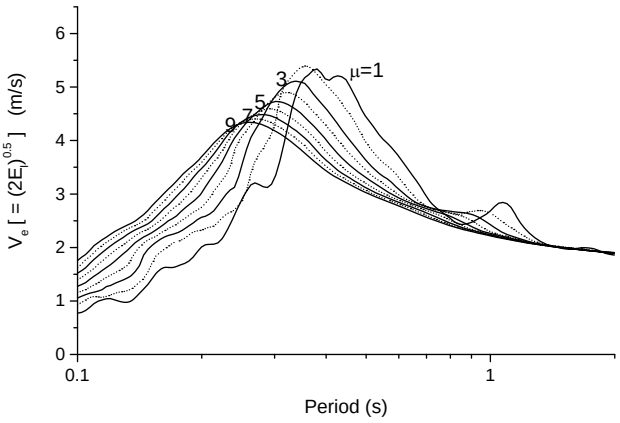



Fig.4 Relative-EEV with Ductility Factors

Acknowledgements:
We used data from NIED K-NET.
Saitama Univ. M. Saitoh

<Information>

Seismograph: K-NET02

Recorded Point: MYG013

Name: Sendai

Observed Time: March 11-14:46:50

Longitude 38.2663N Latitude 140.9293E Altitude 5.00m

Epicentral Distance 175km

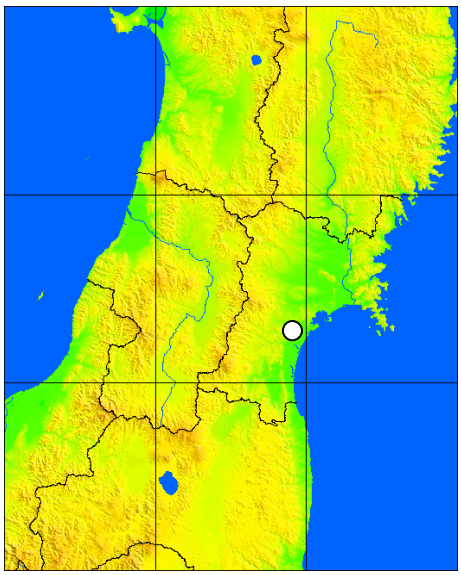
Max. ACC. 1807.8gal

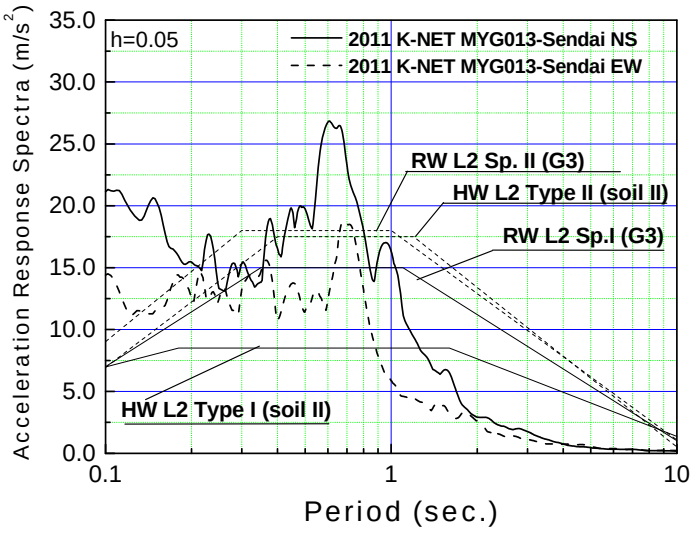
Period of Soil at Site about 0.26s

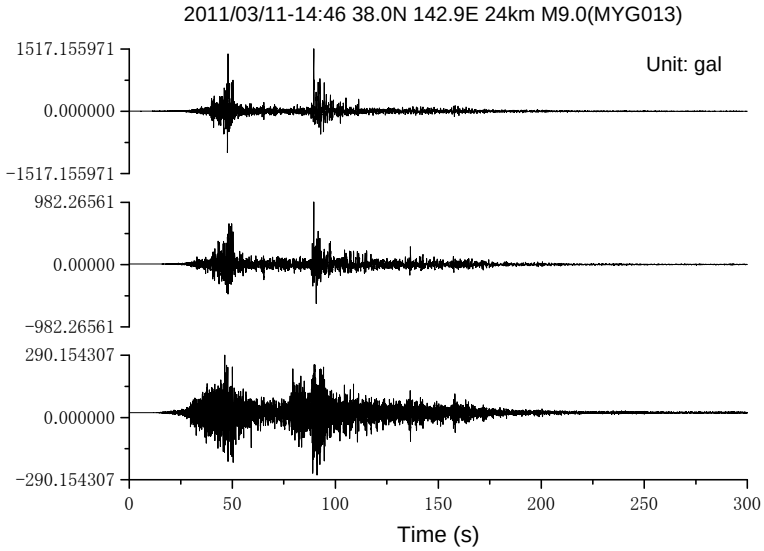
Soil Type(Railway) G3 (Highway) Type II

Acc. Response Spec. Max. 26.84m/s2 (at 0.61s) (5%damping)

Address 3-6-1, Nigatake, Miyaghino-Ku, Sendai, Miyaghi Prefecture





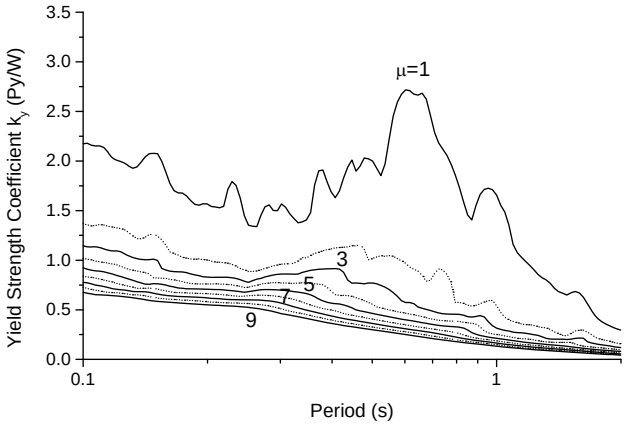



Fig.1 Constant-Ductility Response Spectrum

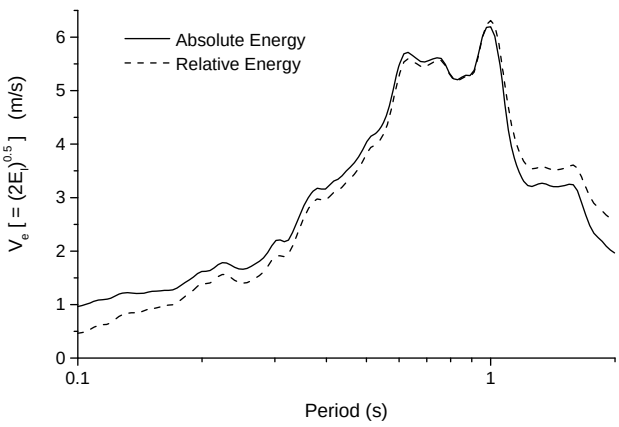



Fig.2 Linear Energy Equivalent Velocity (EEV)

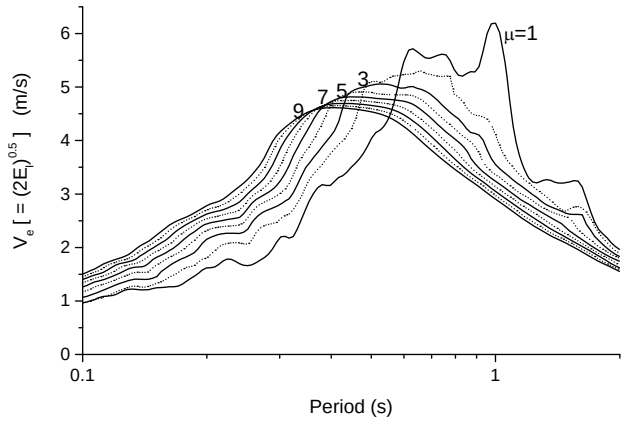



Fig.3 Absolute-EEV with Ductility Factors

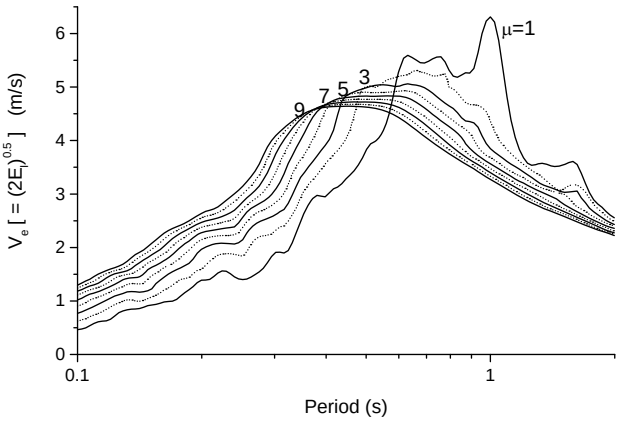



Fig.4 Relative-EEV with Ductility Factors

Acknowledgements:
We used data from NIED K-NET.
Saitama Univ. M. Saitoh

<Information>

Seismograph: K-NET02

Recorded Point: MYG015

Name: Iwanuma

Observed Time: March 11-14:46:49

Longitude 38.1049N Latitude 140.8699E Altitude 3.00m

Epicentral Distance 179km

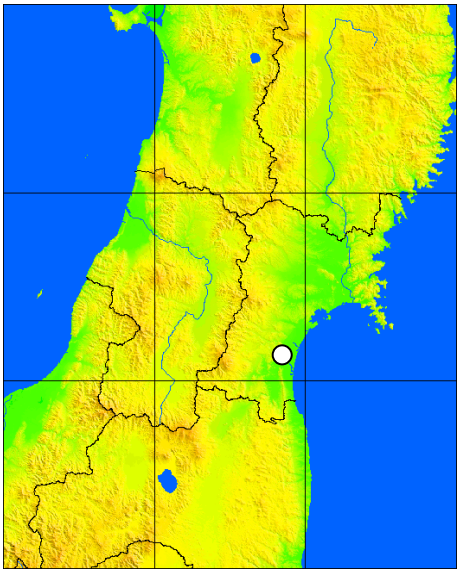
Max. ACC. 433.6gal

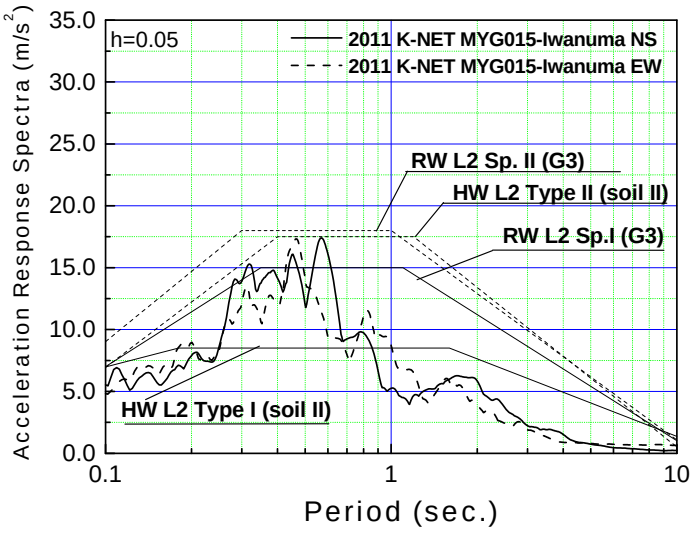
Period of Soil at Site about 0.42s

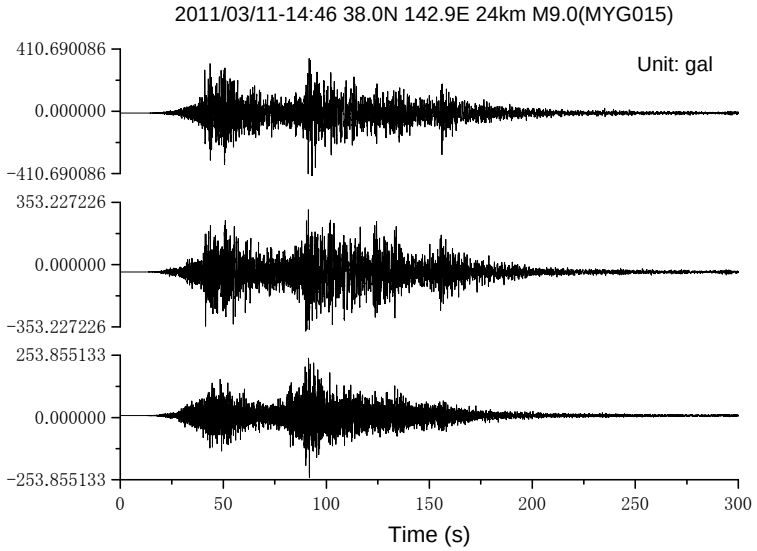
Soil Type(Railway) G3 (Highway) Type II

Acc. Response Spec. Max. 17.41m/s2(at 0.57s) (5%damping)

Address 230-3, 1, Sakura, Iwanuma, Miyaghi Prefecture





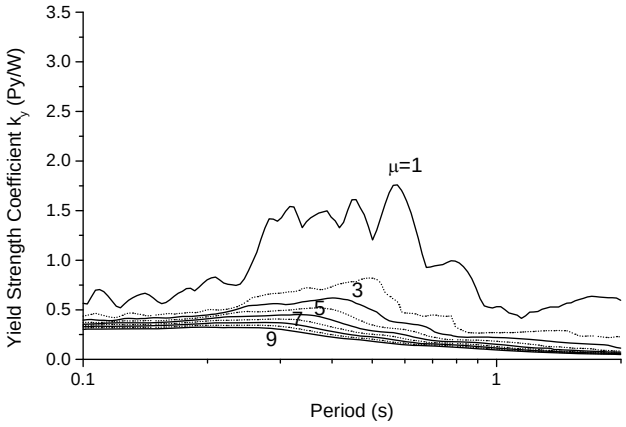



Fig.1 Constant-Ductility Response Spectrum

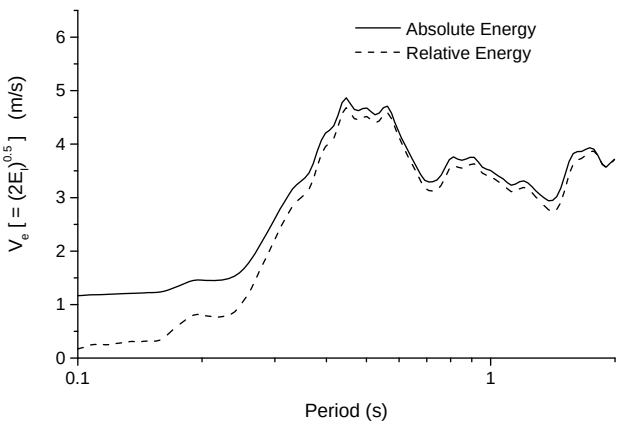



Fig.2 Linear Energy Equivalent Velocity (EEV)

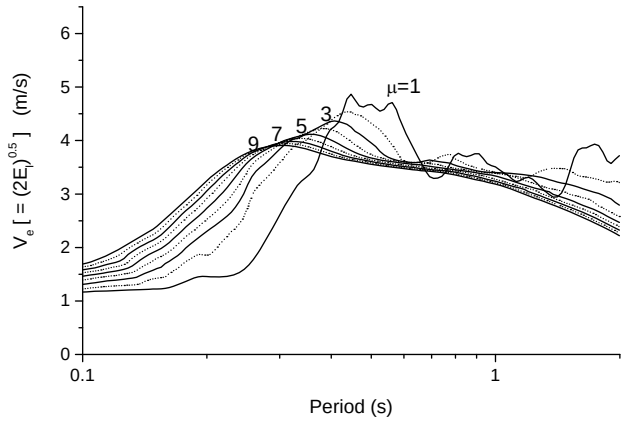



Fig.3 Absolute-EEV with Ductility Factors

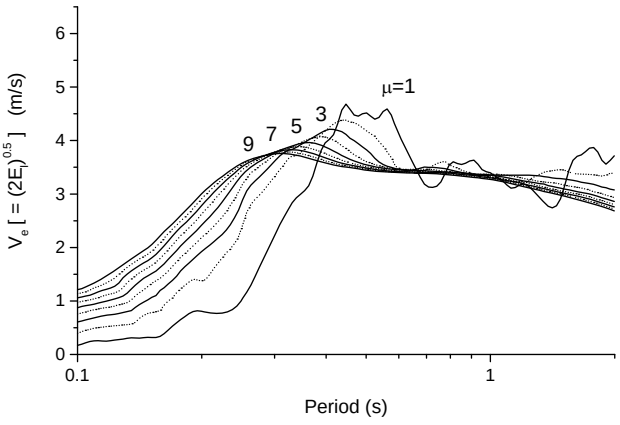



Fig.4 Relative-EEV with Ductility Factors

Acknowledgements:
We used data from NIED K-NET.
Saitama Univ. M. Saitoh

<Information>

Seismograph: K-NET02

Recorded Point: FKS001

Name: Souma

Observed Time: March 11-14:46:50

Longitude 37.7949N Latitude 140.9196E Altitude 9.00m

Epicentral Distance 176km

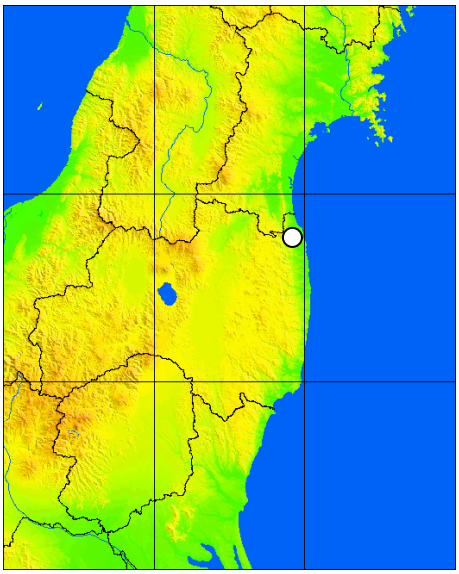
Max. ACC. 682.8gal

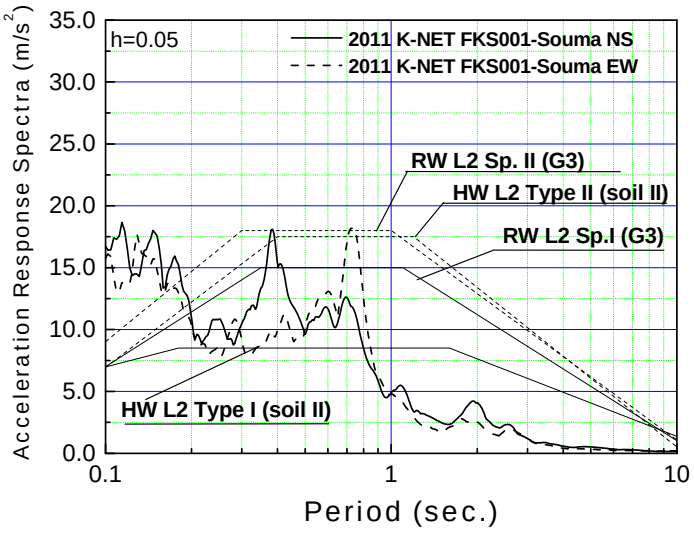
Period of Soil at Site about 0.26s

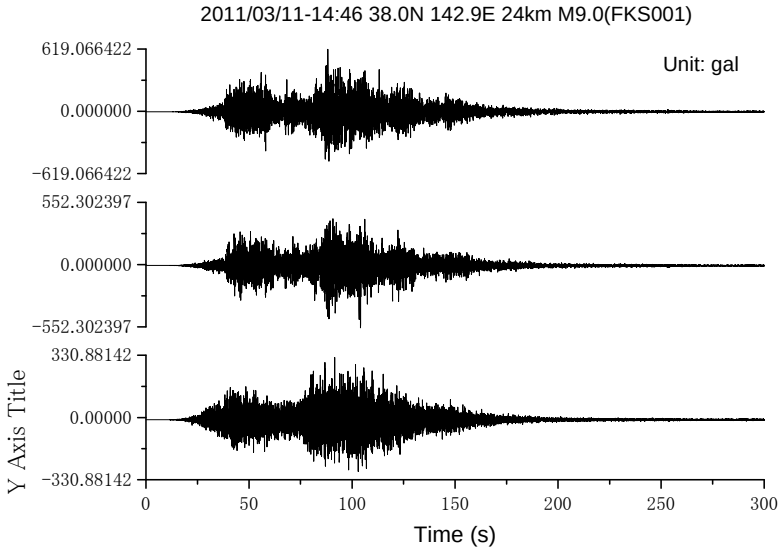
Soil Type(Railway) G3 (Highway) Type II

Acc. Response Spec. Max. 18.21m/s2 (at 0.73s) (5%damping)

Address 65-1 Kawaramachi, Aza, Nakamura, Souma, Fukushima Prefecture





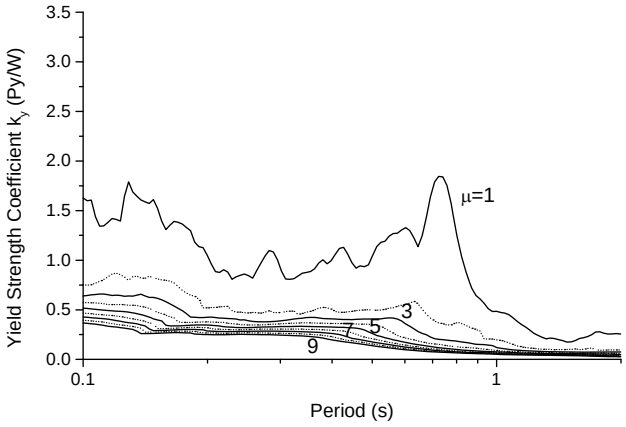



Fig.1 Constant-Ductility Response Spectrum

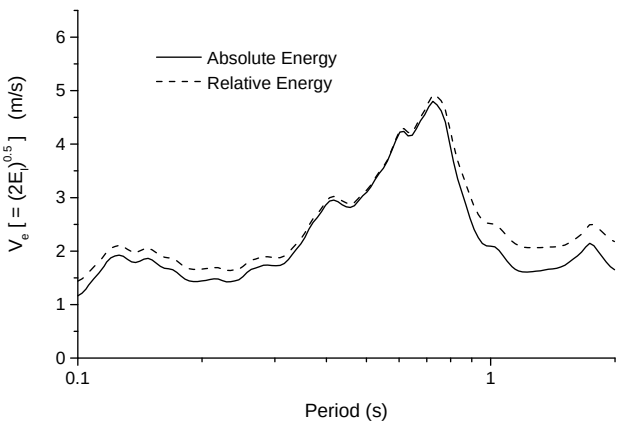



Fig.2 Linear Energy Equivalent Velocity (EEV)

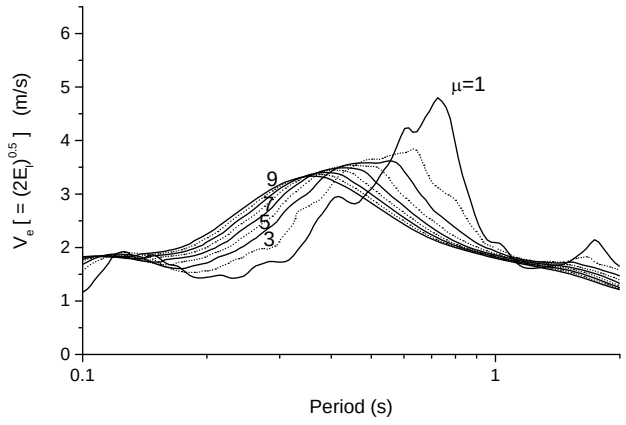



Fig.3 Absolute-EEV with Ductility Factors

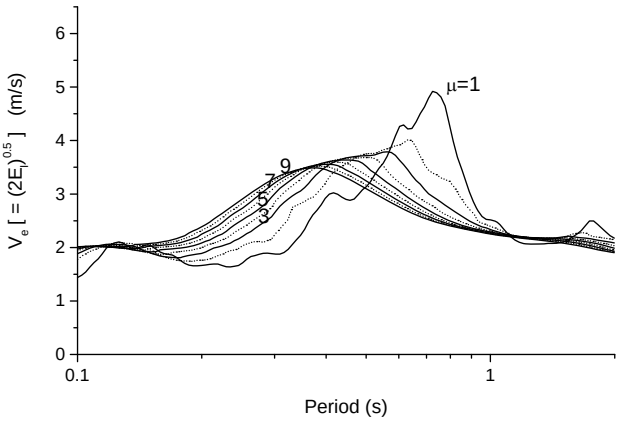



Fig.4 Relative-EEV with Ductility Factors

Acknowledgements:
We used data from NIED K-NET.
Saitama Univ. M. Saitoh

<Information>

Seismograph: K-NET02

Recorded Point: FKS002

Name: Yanagawa

Observed Time: March 11-14:46:55

Longitude 37.8449N Latitude 140.6013E Altitude 42.00m

Epicentral Distance 203km

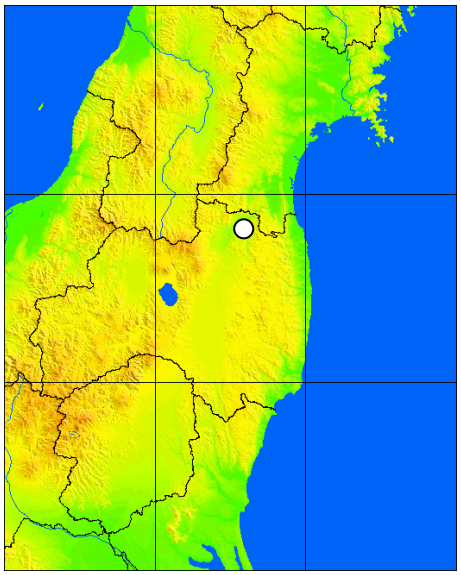
Max. ACC. 629.3gal

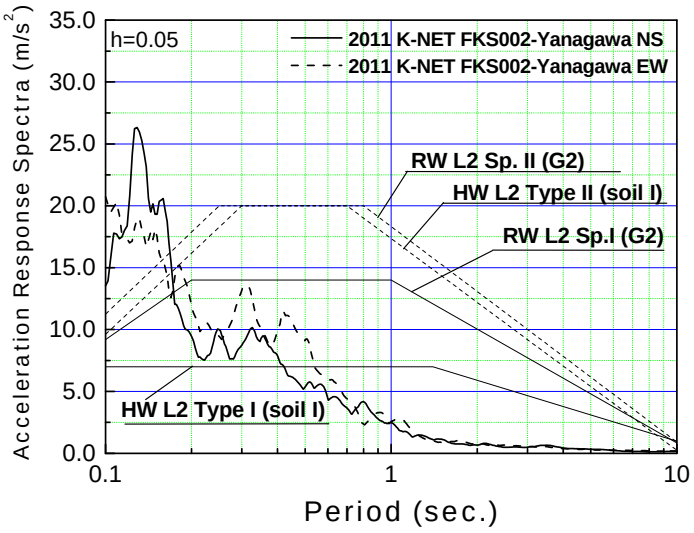
Period of Soil at Site about 0.12s

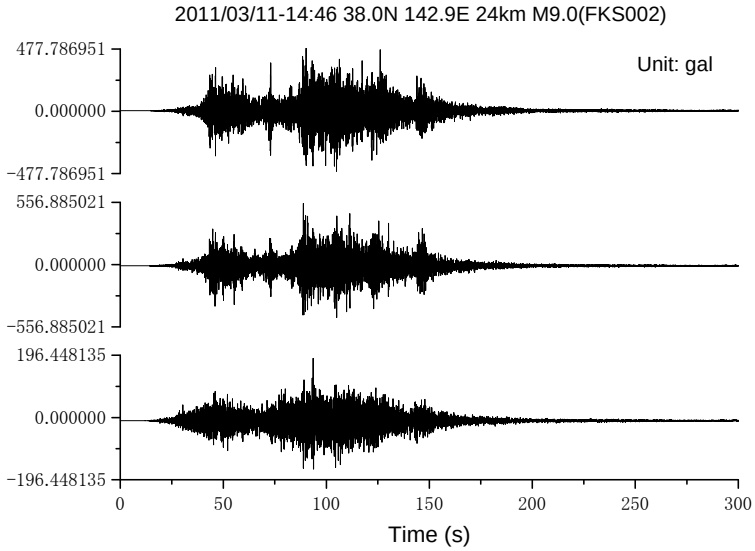
Soil Type(Railway) G2 (Highway) Type I

Acc. Response Spec. Max. 26.33m/s2(0.13s) (5%damping)

Address 20, Gotanda, Yanagawa-Chyo, Date, Fukushima Prefecture





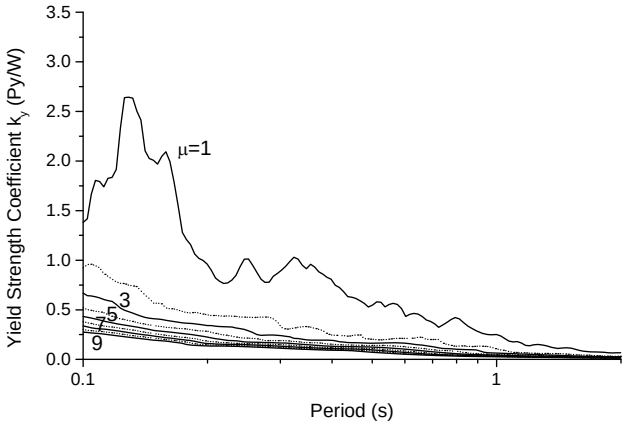



Fig.1 Constant-Ductility Response Spectrum

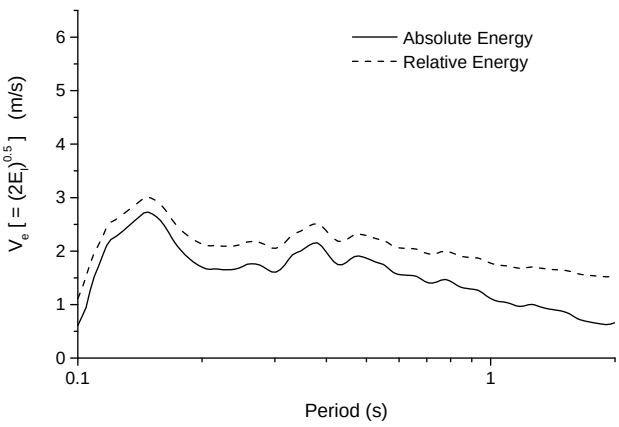



Fig.2 Linear Energy Equivalent Velocity (EEV)

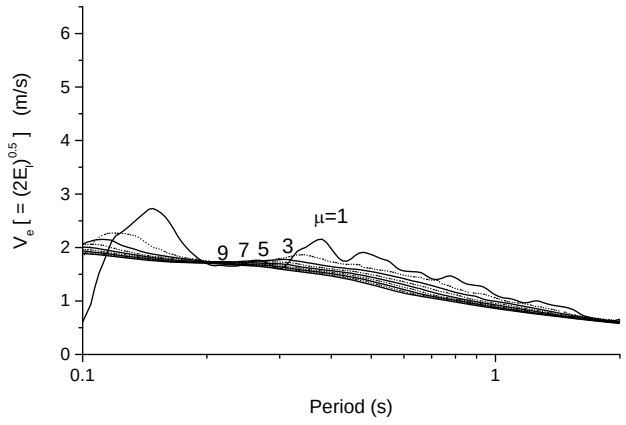



Fig.3 Absolute-EEV with Ductility Factors

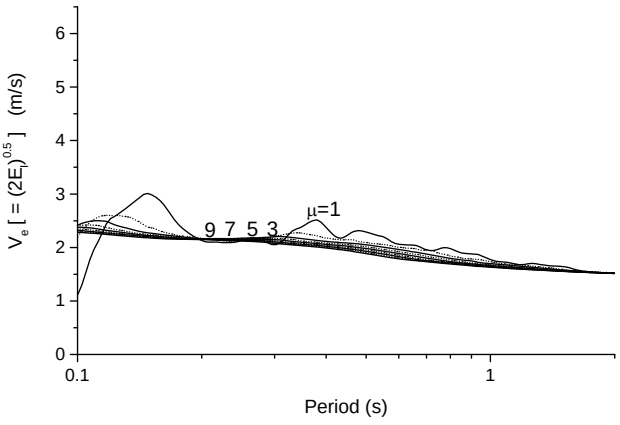



Fig.4 Relative-EEV with Ductility Factors

Acknowledgements:
We used data from NIED K-NET.
Saitama Univ. M. Saitoh

<Information>

Seismograph: K-NET02

Recorded Point: FKS003

Name: Fukushima

Observed Time: March 11-14:46:58

Longitude 37.7613N Latitude 140.4799E Altitude 64.00m

Epicentral Distance 215km

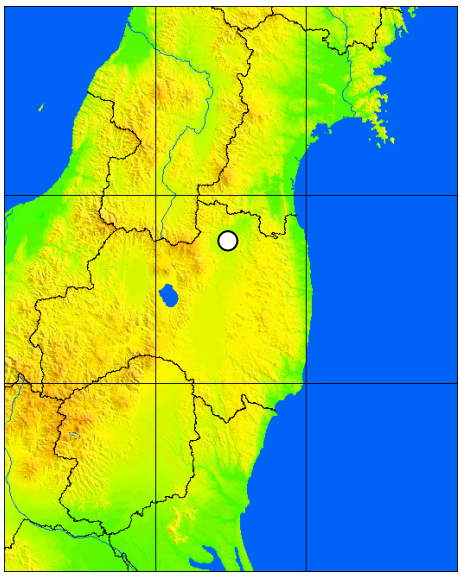
Max. ACC. 329.1gal

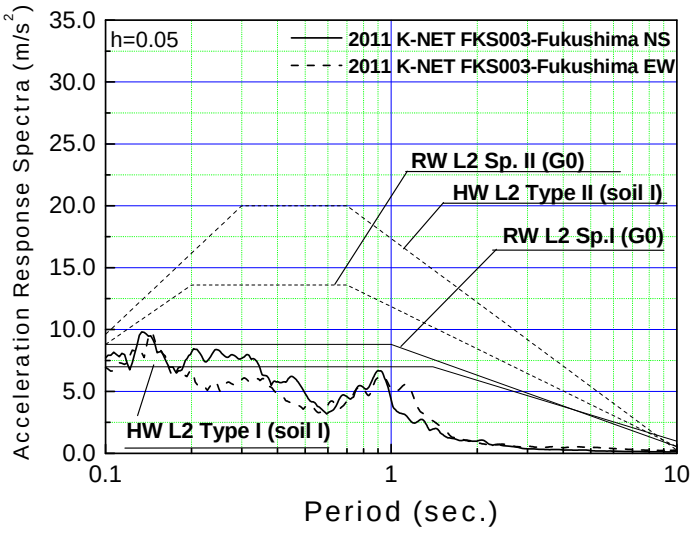
Period of Soil at Site about 0.13s

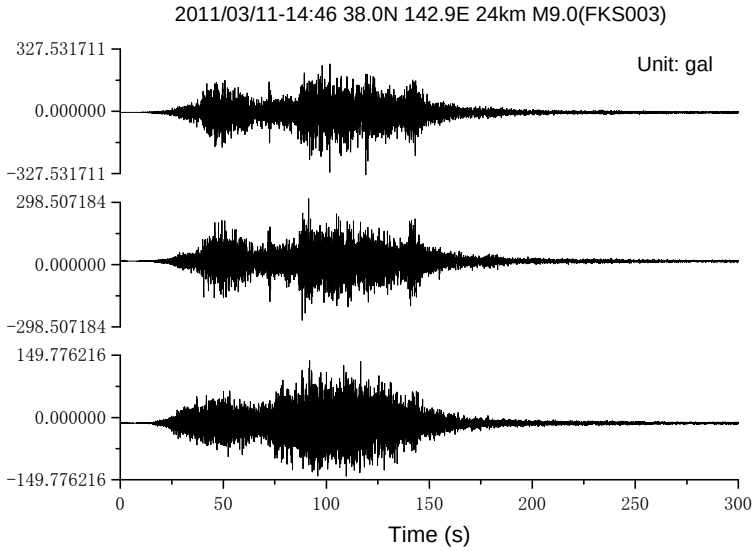
Soil Type(Railway) G0 (Highway) Type I

Acc. Response Spec. Max. 9.82m/s2 (at 0.13s) (5%damping)

Address 5-20, Sakuraghi-Chyo, Fukushima, Fukushima Prefecture





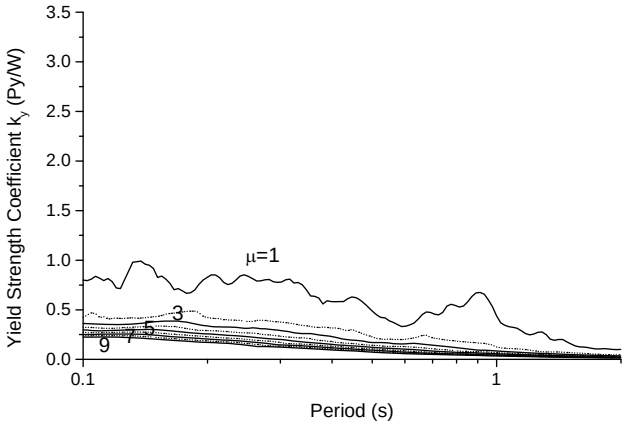



Fig.1 Constant-Ductility Response Spectrum

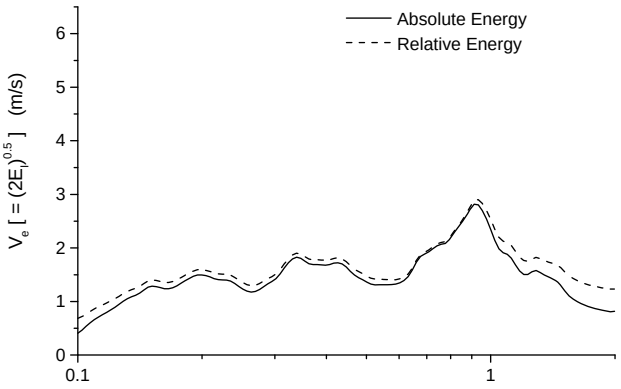



Fig.2 Linear Energy Equivalent Velocity (EEV)

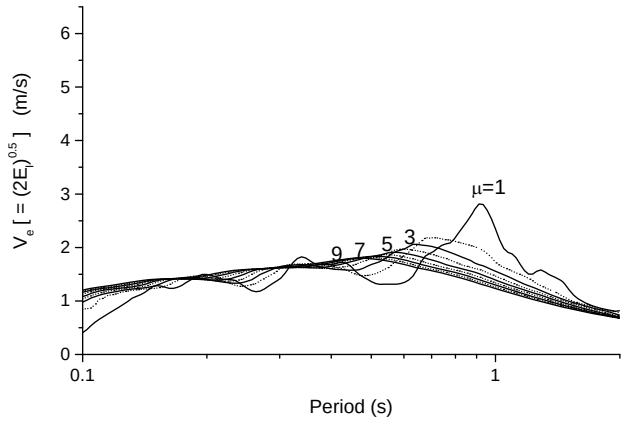



Fig.3 Absolute-EEV with Ductility Factors

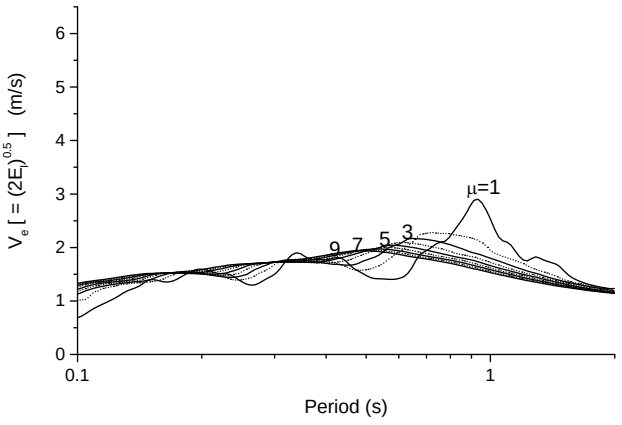



Fig.4 Relative-EEV with Ductility Factors

Acknowledgements:
We used data from NIED K-NET.
Saitama Univ. M. Saitoh

<Information>

Seismograph: K-NET02

Recorded Point: FKS019

Name: Nihonmatsu

Observed Time: March 11-14:46:57

Longitude 37.6030N Latitude 140.4368E Altitude 235.00m

Epicentral Distance 221km

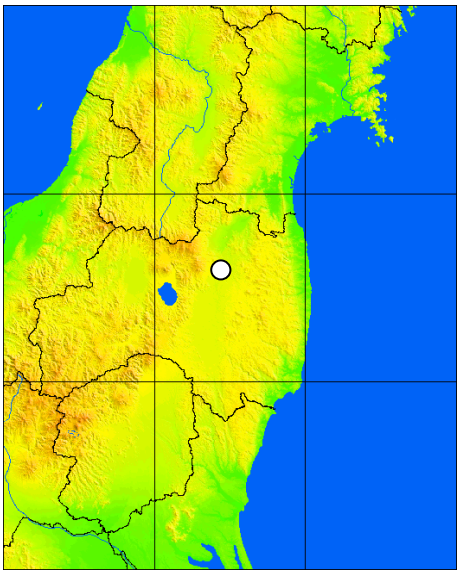
Max. ACC. 461.4gal

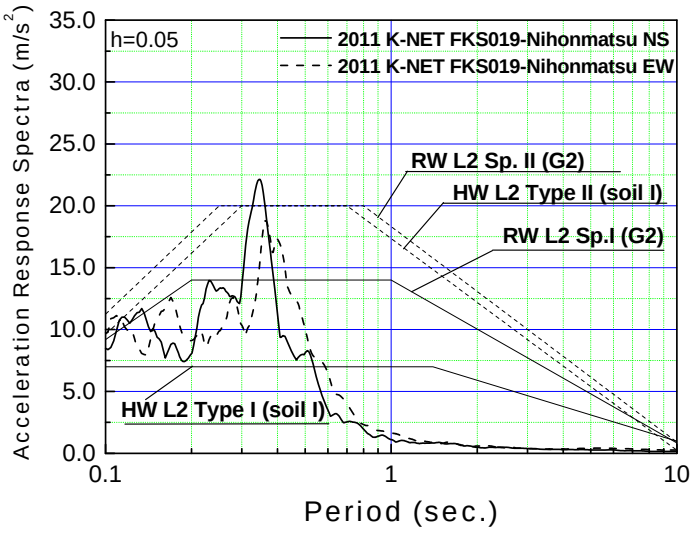
Period of Soil at Site about 0.21s

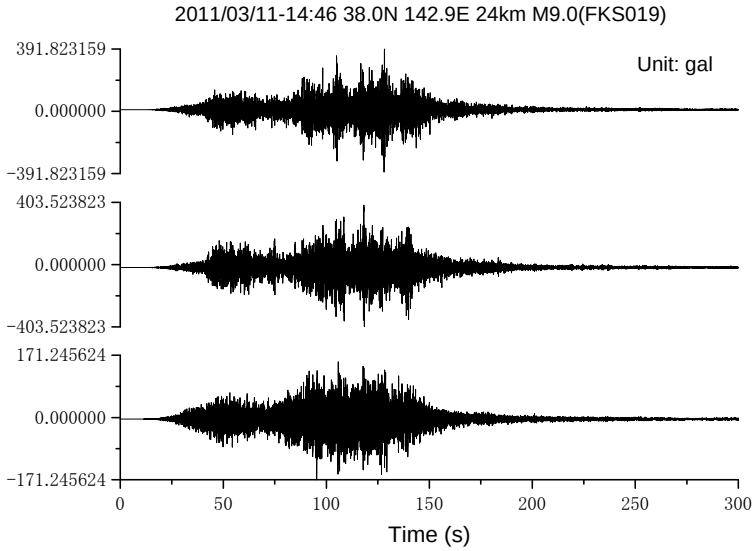
Soil Type(Railway) G2 (Highway) Type I

Acc. Response Spec. Max. 22.12m/s2(at 0.35s) (5%damping)

Address 2-22, Kakunai, Nihonmatsu, Fukushima Prefecture





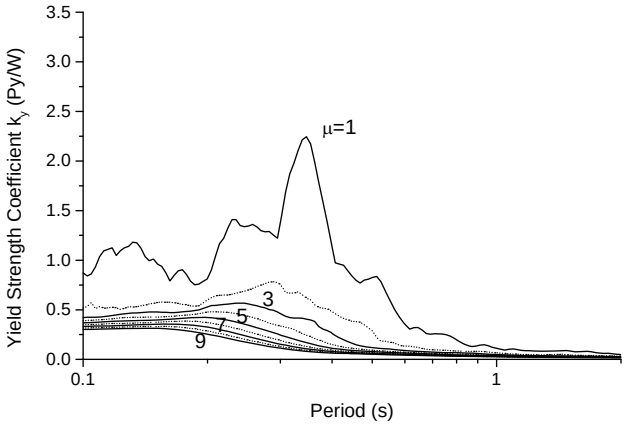



Fig.1 Constant-Ductility Response Spectrum

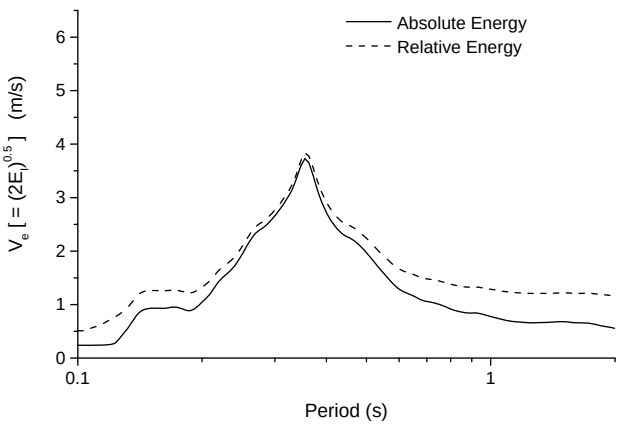



Fig.2 Linear Energy Equivalent Velocity (EEV)

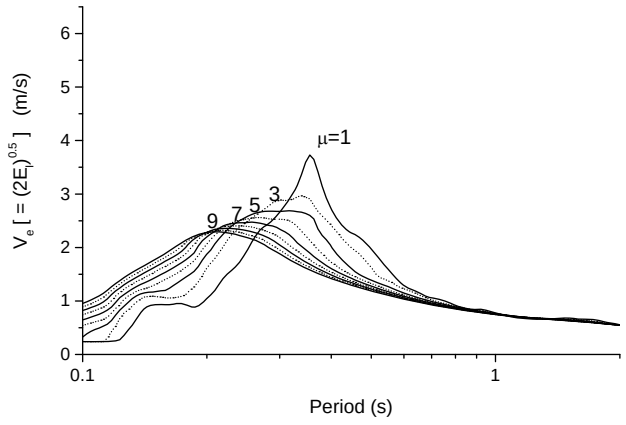



Fig.3 Absolute-EEV with Ductility Factors

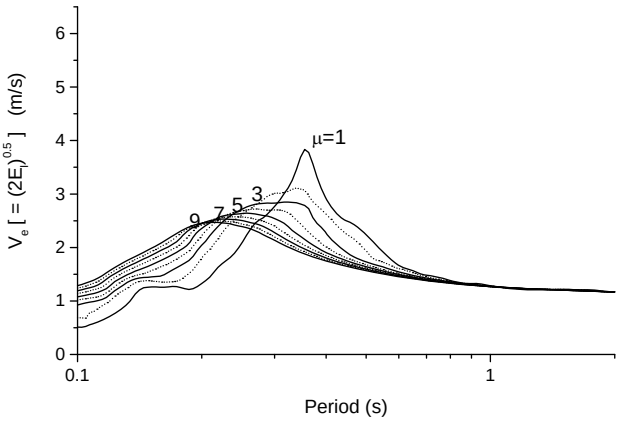



Fig.4 Relative-EEV with Ductility Factors

Acknowledgements:
We used data from NIED K-NET.
Saitama Univ. M. Saitoh

<Information>

Seismograph: K-NET02

Recorded Point: TCG001

Name: Kuroiso

Observed Time: March 11-14:47:10

Longitude 36.9417N Latitude 140.0828E Altitude254.80m

Epicentral Distance 275km

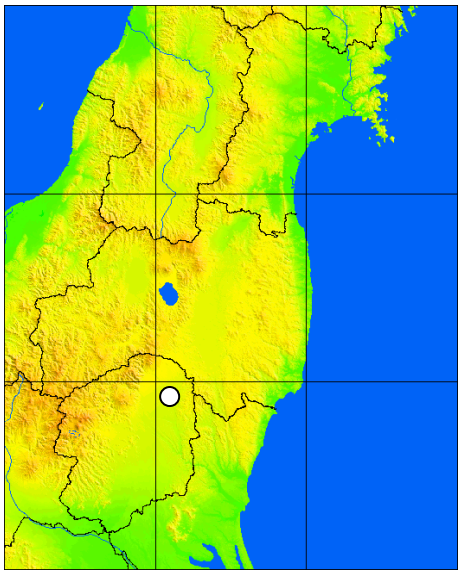
Max. ACC. 485.7gal

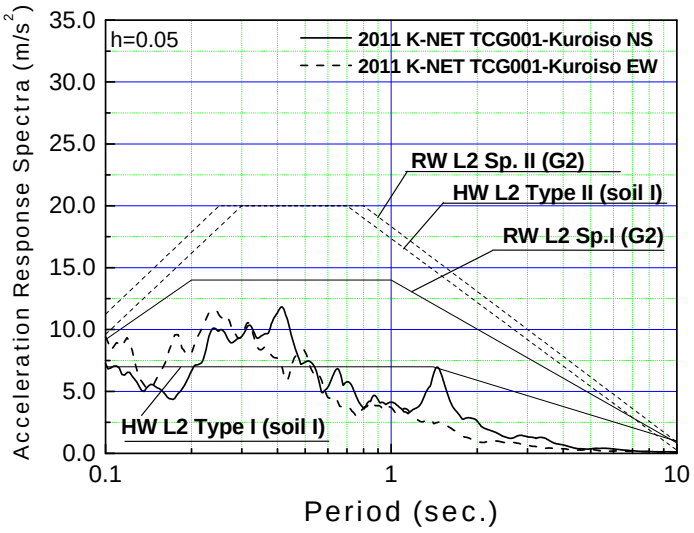
Period of Soil at Site about 0.11s

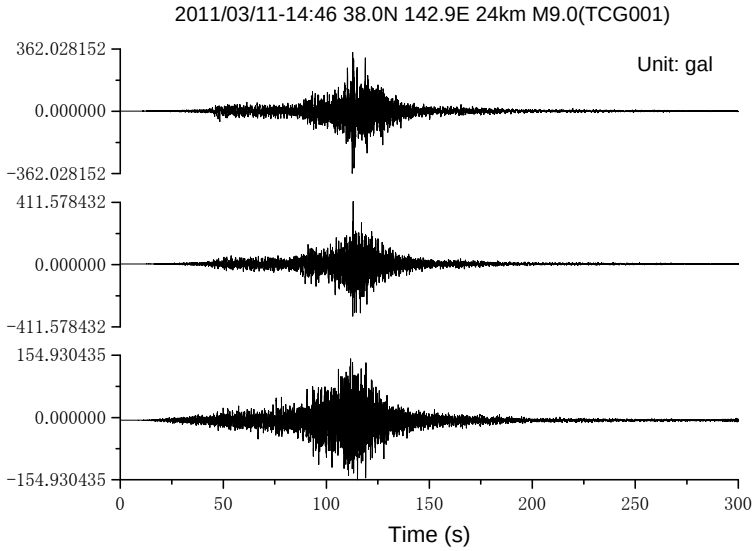
Soil Type(Railway) G2 (Highway) Type I

Acc. Response Spec. Max. 11.84m/s2(at 0.41s) (5%damping)

Address 1477-1, Aza-Nabekakehara, Nabekake, Nasushiobara, Tochighi Prefecture





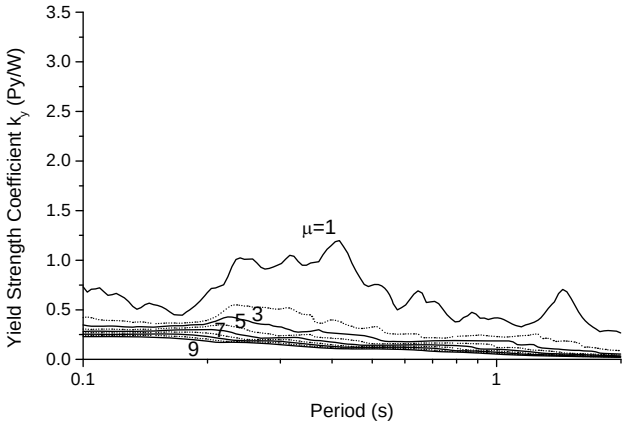



Fig.1 Constant-Ductility Response Spectrum

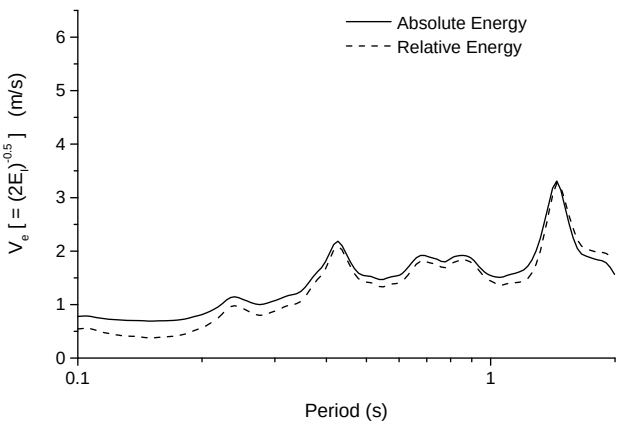



Fig.2 Linear Energy Equivalent Velocity (EEV)

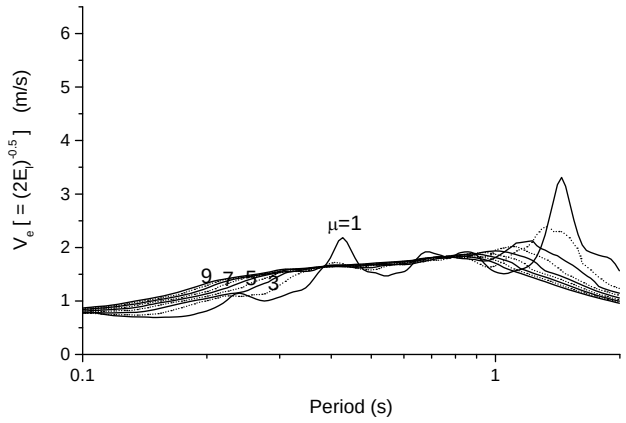



Fig.3 Absolute-EEV with Ductility Factors

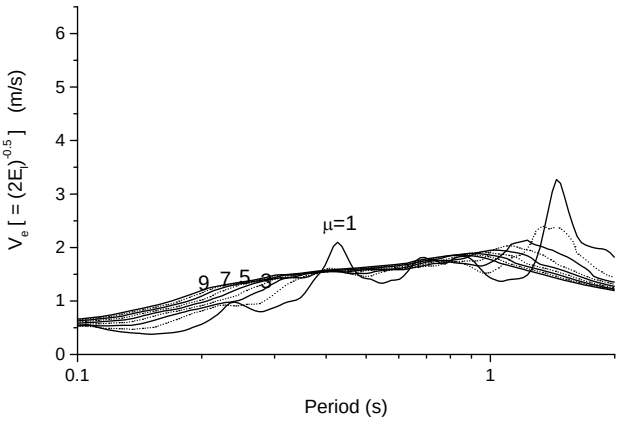



Fig.4 Relative-EEV with Ductility Factors

Acknowledgements:
We used data from NIED K-NET.
Saitama Univ. M. Saitoh

<Information>

Seismograph: K-NET02

Recorded Point: TCG014

Name: Moteghi

Observed Time: March 11-14:47:09

Longitude 36.5450N Latitude 140.1742E Altitude130.00m

Epicentral Distance 291km

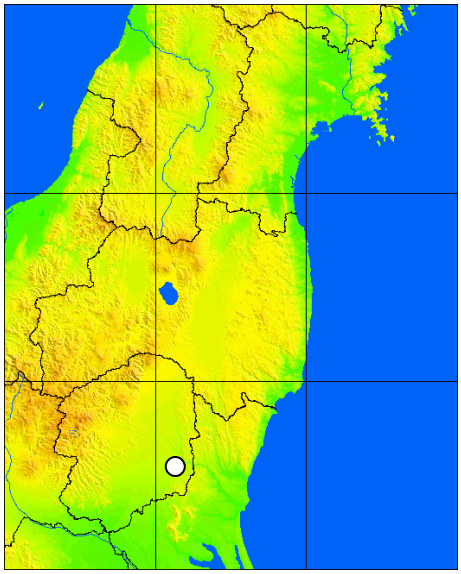
Max. ACC. 1291.1gal

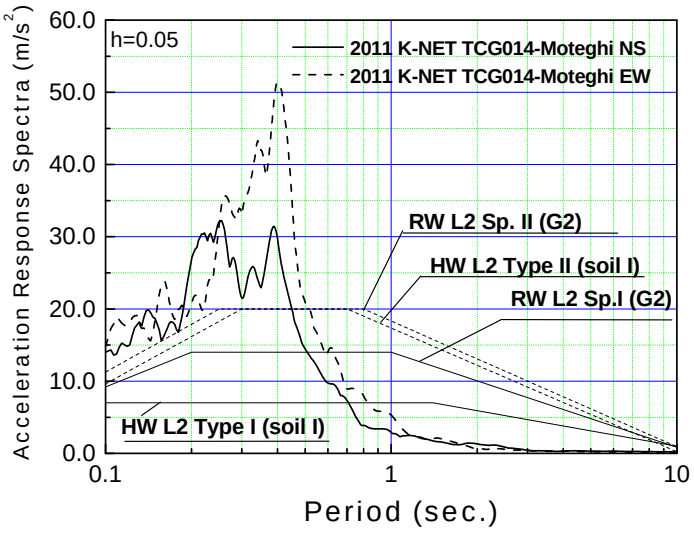
Period of Soil at Site about 0.17s

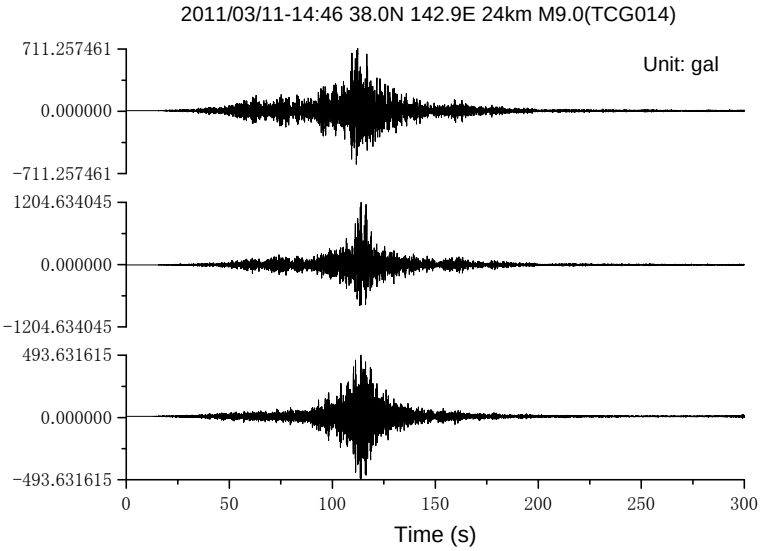
Soil Type(Railway) G2 (Highway) Type I

Acc. Response Spec. Max. 51.37m/s2(at 0.40s) (5%damping)

Address 2758, Aza-Namimatsu, Oaza-Koido, Moteghi-Chyo, Haga-Gun, Tochighi Prefecture





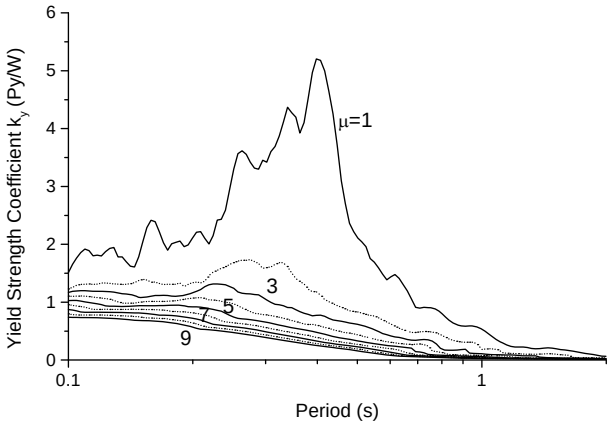



Fig.1 Constant-Ductility Response Spectrum

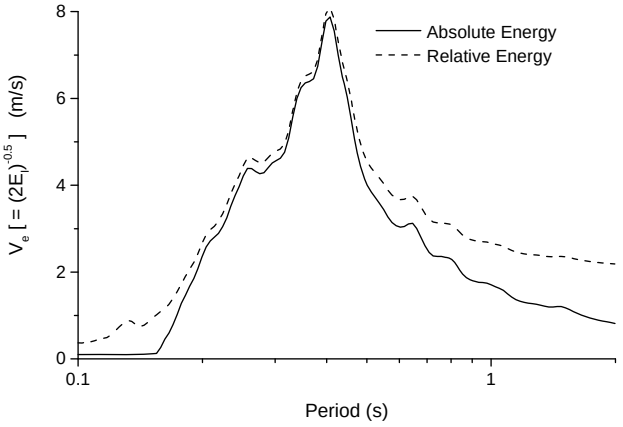



Fig.2 Linear Energy Equivalent Velocity (EEV)

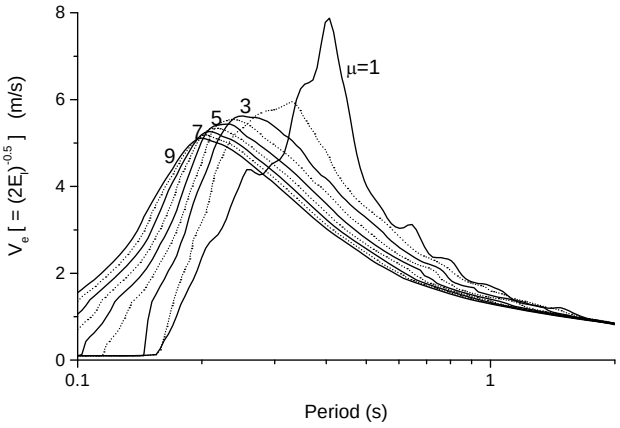



Fig.3 Absolute-EEV with Ductility Factors

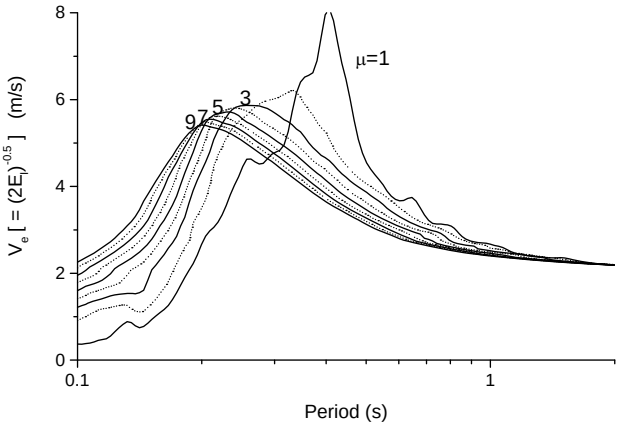



Fig.4 Relative-EEV with Ductility Factors

Acknowledgements:
We used data from NIED K-NET.
Saitama Univ. M. Saitoh

<Information>

Seismograph: K-NET02

Recorded Point: IBR003

Name: Hitachi

Observed Time: March 11-14:47:05

Longitude 36.5915N Latitude 140.6453E Altitude57.50m

Epicentral Distance 254km

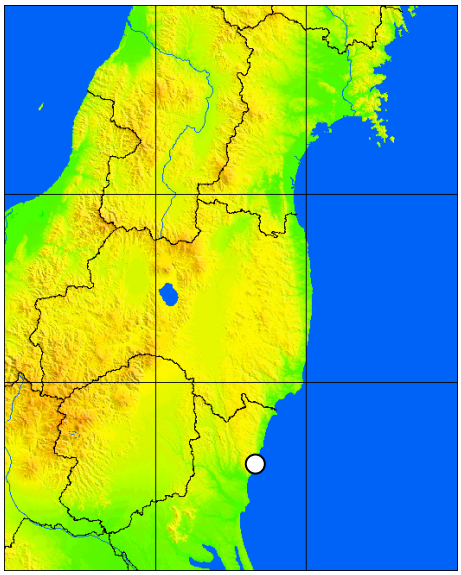
Max. ACC. 1845.2gal

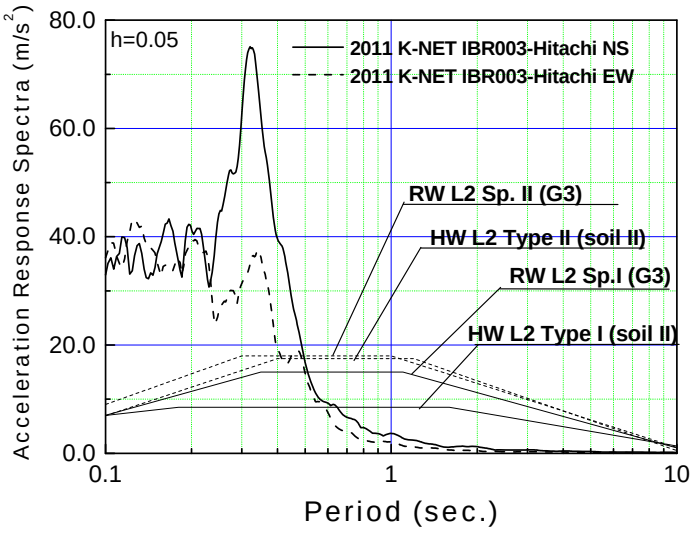
Period of Soil at Site about 0.33s

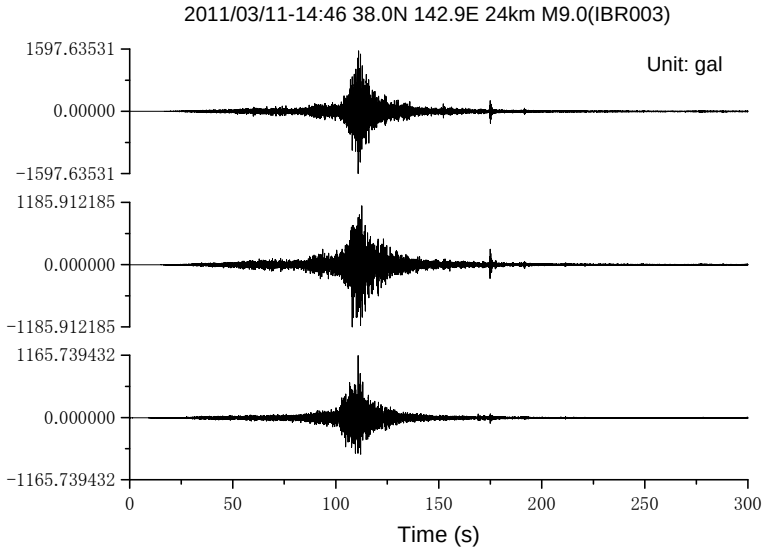
Soil Type(Railway) G3 (Highway) Type II

Acc. Response Spec. Max. 75.09m/s2(at 0.32s) (5%damping)

Address 2-15, Sukegawa-Chyo, Hitachi, Ibaraki Prefecture





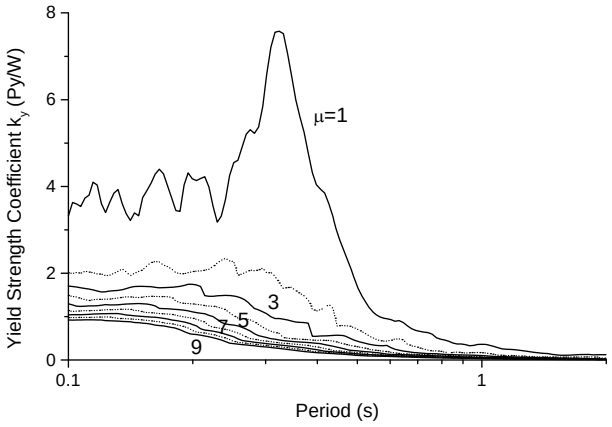



Fig.1 Constant-Ductility Response Spectrum

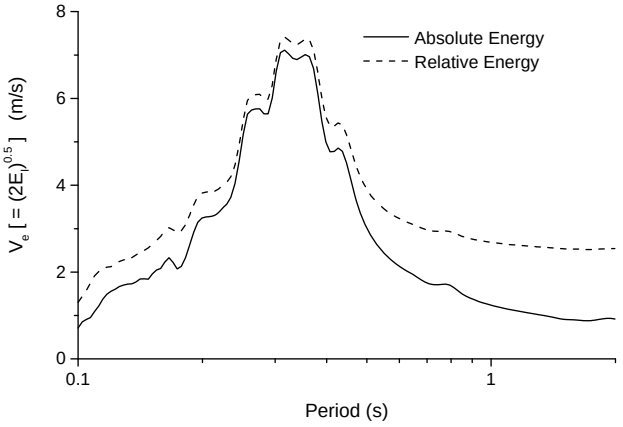



Fig.2 Linear Energy Equivalent Velocity (EEV)

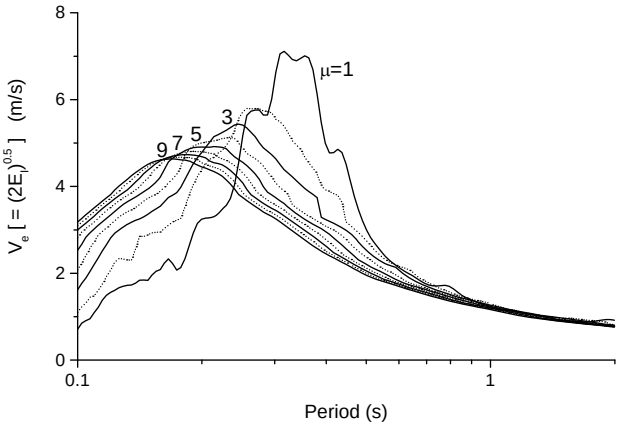



Fig.3 Absolute-EEV with Ductility Factors

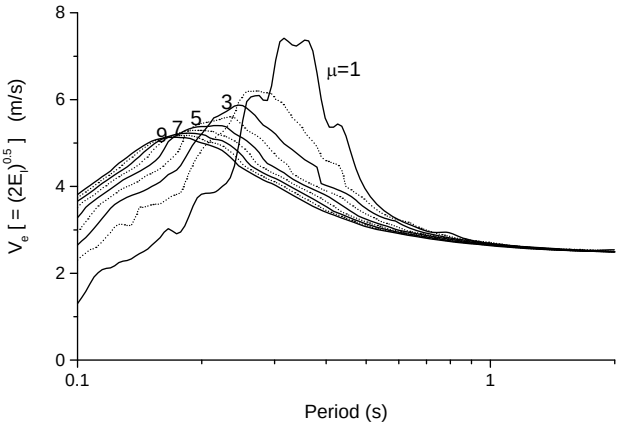



Fig.4 Relative-EEV with Ductility Factors

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