

International Institute of Seismology and Earthquake Engineering



Strong Motion Observation in Japan

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Contents

- Brief History of strong motion observation in Japan
- Strong Motion Instruments
- Sensor Configuration
- Data Processing
- Recent Strong Motion Networks in Japan



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Purpose

- How does the ground shake?
- How do buildings respond?
- How do earthquakes cause damage?



Brief History in Japan

- Destructive Earthquakes
- Strong Motion Accelerometer Committee
- Strong-Motion Earthquake Observation Council
 - Specifications of Past and Present Instruments



| # | Date | Location | Casualties |
|----|------------|---------------|---------------|
| 1 | 1923/09/01 | S Kanto | Dead: 142,807 |
| 2 | 1925/05/23 | N Tajima | Dead: 428 |
| 3 | 1927/03/07 | NW Kyoto | Dead: 2,925 |
| 4 | 1930/11/26 | N Izu | Dead: 272 |
| 5 | 1933/03/03 | Off Sanriku | Dead: 3,064 |
| 6 | 1943/09/10 | Tottori | Dead: 1,083 |
| 7 | 1944/12/07 | Off Tokaido | Dead: 1,223 |
| 8 | 1945/01/13 | S Aichi Pref. | Dead: 2,306 |
| 9 | 1946/12/21 | Off Nankaido | Dead: 1,330 |
| 10 | 1948/06/28 | Fukui | Dead: 3,769 |

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| # | Date | Location | Casualties |
|----|------------|--------------------|------------|
| 11 | 1964/06/16 | Off Niigata | Dead: 26 |
| 12 | 1968/05/16 | Off Aomori | Dead: 52 |
| 13 | 1974/05/09 | Off Izu Pen. | Dead: 30 |
| 14 | 1978/01/14 | Izu-Oshima | Dead: 25 |
| 15 | 1978/06/12 | Off Miyagi | Dead: 28 |
| 16 | 1983/05/26 | C Japan Sea | Dead: 104 |
| 17 | 1984/09/14 | E Nagano Pref. | Dead: 29 |
| 18 | 1993/01/15 | Off Kushiro | Dead: 2 |
| 19 | 1993/07/12 | SW Off Hokkaido | Dead: 231 |
| 20 | 1994/12/28 | Far Off Sanriku | Dead: 3 |

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| # | Date | Location | Casualties |
|----|------------|--------------------------|--------------------------|
| 21 | 1995/01/17 | S. Hyogo Pref. (Kobe) | Dead: 6,433 |
| 22 | 2001/03/24 | Aki-nada | Dead: 2 |
| 23 | 2003/09/26 | Off Tokachi | Missing: 2 |
| 24 | 2004/10/23 | Chuetsu, Niigata | Dead: 68 |
| 25 | 2007/03/25 | Noto Pen. | Dead: 1 |
| 26 | 2007/07/16 | Off Chuetsu | Dead: 15 |
| 27 | 2008/06/14 | S. Inland, Iwate | Dead: 13, Missing: 10 |

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Brief History in Japan Strong Motion Accelerometer Committee

- 1948 Fukui Earthquake
- I 1951 Strong Motion Accelerometer Committee was established to develop strong motion instruments (some professors, researchers and engineers joined)
- 1953 the prototype instrument SMAC was developed



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Brief History in Japan First model SMAC





Brief History in Japan Strong-motion Earthquake Obs. Council

- 1967 Strong-motion Earthquake Observation Council was established (secretariat in NIED)
- Many public bodies join (ERI, NIED, BRI, PWRI, PHRI, JR, NTT, etc.)
- Aims at promotion, coordination and publication of strong motion observation and its results



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Strong motion instruments Outline

- Improvement of instruments for 50 years
 - Sensor: Pendulum -> Feedback
 - Signal processing: Analog -> Digital
 - Recording medium: Paper -> IC Memory
 - Size & weight: -> Small and light
 - Handling: -> Easy



SMAC-B



| SMAC-B (1957) |
|------------------------------|
| Pendulum |
| Analog (Mechanical) |
| Stylus Paper |
| DC~10 Hz |
| \pm 1000 cm/s ² |
| 25 cm/s ² /mm |
| 10 cm/s ² |
| 3 components |
| - |





SMAC-M



| SMAC-M (1972) |
|------------------------------|
| Feedback |
| Analog (Electrical) |
| Cassette Tape |
| 0.1~30 Hz |
| \pm 1000 cm/s ² |
| 1 cm/s ² /mV |
| 5 cm/s ² |
| 3 |
| - |





SMAC-MD



| SMAC-MD (1988) |
|-------------------------------|
| Feedback |
| Digital (16-bit) |
| Memory Card |
| 0.02~30 Hz |
| \pm 1000 cm/s ² |
| 0.03 cm/s ² /digit |
| 0.5~32 cm/s ² |
| 9 (max) |
| 10 sec. |





SMAC-MDU



SMAC-MDU (1997)Feedback Digital (24-bit) **Memory Card** DC~30 Hz \pm 2000 cm/s² 0.0025 cm/s²/digit 0.1~99.9 cm/s² 18 (max) 0~60 sec.





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Strong motion instruments Features of recent models

- High dynamic range
- Pre-trigger recording
- Clock equipment
- Miniaturization
- Programmable control
- Telemetric handling
- Quick data processing



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Strong motion instruments Sensor configuration #1

Ground motion and site effect





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Strong motion instruments Sensor configuration #2

Building response and soil-structure interaction





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Strong motion instruments Sensor installation #1





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Data processing Process in BRI

- Collecting binary data files from the stations (via telephone line)
- Validating data (waveforms and Fourier spectra)
- Converting binary data files to human readable (usually ASCII text) files
- Collecting earthquake information (from JMA through the Internet)
- Compiling record information (with additional information)
- Entering records in database



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Data processing Information in database

| Site | Name (and/or unique code), address |
|--------|---|
| | Location (latitude, longitude, altitude) |
| | Ground condition |
| | Observation object (ground, building, or other structure) |
| Event | Origin time |
| | Location of focus (latitude, longitude, depth) |
| | Magnitude |
| | Place name of epicenter (name of earthquake) |
| Record | Trigger time |
| | Sampling frequency |
| | Number of steps |
| | Number of components |
| | Place and direction (for each component) |
| | Peak amplitude (and/or other intensity index) |



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Data processing Search interface



Strong Motion Database

Search target

Search Target: Records 💌

Search (Records)

| Magnitude | 2 🖌 | JMA magnitude |
|-------------------|---------|---|
| Depth (km) | 2 🗸 | Focal depth (km) |
| Epicenter | | Epicenter |
| Period | from to | (yyyy-mm-dd) |
| Station name | | Name of station (or building) |
| Address | | Address of station |
| Distance (km) | 2 🗸 | Distance between station and epicenter (km) |
| Peak Acc.(gal) | 2 🗸 | of reference sensor (on GL or at building basement) |
| Seismic Intensity | 2 🗸 | of reference sensor (on GL or at building basement) |
| | Search | All records will be listed if you search without any conditions |



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Recent Networks in Japan Outline

- JMA seismic intensity network
- K-NET and KiK-net by NIED
- Seismic Intensity Information Network of Local Governments
 - Other National Research Institutes and Public Bodies (BRI, NILIM, PARI, ERI, Yokohama City, etc)



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Recent Networks in Japan Three Major Networks

| | JMA | K-NET, KiK-net | Local Gov. |
|---------------|------------------|--------------------------|--------------------------|
| Stations | 600 | 1,700 | 2,600 |
| Primary Info. | I _{JMA} | PGA, (I _{JMA}) | I _{JMA} , (PGA) |
| within | 2~3 min. | < 10 min? | 2~5 min? |
| by | Broadcast | E-mail | Special net |
| Acc. Data | Available | Available | N. A. |
| within | Afterwards | 2~3 days | |
| by | CD-ROM | Web site | via JMA |



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Recent Networks in Japan JMA seismic intensity scale

- Defined in 1996
- Calculated from filtered 3-comp. acceleration
- Compatible with old scale

 $I_{\rm JMA} = 2\log a_0 + 0.94$





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Recent Networks in Japan JMA seismic intensity scale

| Scale | Explanation | |
|-------|--|--|
| 7 | In most buildings, wall tiles and windowpanes are damaged and fall. In some cases, reinforced concrete-block walls collapse. | |
| 6+ | In many buildings, wall tiles and windowpanes are damaged and fall. Most unreinforced concrete-block walls collapse. | |
| 6- | 6- In some buildings, wall tiles and windowpanes are damaged and fall. | |
| 5+ | In many cases, unreinforced concrete-block walls collapse and tombstones overturn. Many automobiles stop due to difficulty to drive. | |



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Recent Networks in Japan JMA seismic intensity scale

| S | Scale | Explanation |
|-----------------|-------|--|
| 5- Most peop | | Most people try to escape from a danger. Some people find it difficult to move |
| _ | 4 | Many people are frightened. Some people try to escape from a danger. Most sleeping people awake. |
| | 3 | Felt by most people in the building. Some people are frightened. |
| | 2 | Felt by many people in the building. Some sleeping people awake. |
| | 1 | Felt by only some people in the building. |
| | 0 | Imperceptible to people. |



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Recent Networks in Japan JMA stations





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Recent Networks in Japan K-NET & KiK-net stations





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Recent Networks in Japan Local government stations





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Recent Networks in Japan Stations of major networks





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Recent Networks in Japan Example (PGA, 2004 Chuetsu Eq.)





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Recent Networks in Japan Example (I_{JMA}, 2004 Chuetsu Eq.)





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Recent Networks in Japan Example (I_{JMA}, 2004 Chuetsu Eq.)





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Recent Networks in Japan NILIM, MLIT

700 stations along roads and rivers for urgent inspection of facilities



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Recent Networks in Japan PARI

60 stations at ports



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Recent Networks in Japan ERI, University of Tokyo

Southern Kanto and Ashigara plain



Recent Networks in Japan Yokohama City

150 stations for disaster measures



Recent Networks in Japan Others

- Urban Renaissance Agency (UR)
- Nippon Telegraph and Telephone Corporation (NTT)
- Japan Railway Company (JR)
- Central Research Institute of Electric Power Industry (CRIEPI)
- Universities
- General Contractors