Chapter 27: Seismogram

Introduction

A *seismogram* is a graphical output or digital record that captures the motion of the ground during an earthquake. It is produced by an instrument called a *seismograph* or *seismometer*. The primary purpose of a seismogram in earthquake engineering is to record the seismic waves generated by tectonic activity, enabling engineers and seismologists to analyze the behavior of ground motion, predict seismic impacts on structures, and design earthquake-resistant infrastructure.

Understanding seismograms is crucial for civil engineers, as these records directly inform site-specific seismic hazard analysis, structural response simulations, and building code formulations. This chapter explores the nature, interpretation, and application of seismograms in detail.

27.1 Components of a Seismogram

A seismogram records the movement of the earth's surface in three components:

1. **Vertical (Z-axis)**
   - Captures up-and-down motion.
   - Usually affected by P-waves (primary waves).
2. **Horizontal - North-South (N-S)**
   - Captures lateral ground motion in the N-S direction.
   - Sensitive to both S-waves and surface waves.
3. **Horizontal - East-West (E-W)**
   - Captures lateral ground motion in the E-W direction.
   - Also responsive to S-waves and surface waves.

Each component provides independent but complementary information about the direction and magnitude of seismic motion.

27.2 Types of Seismograms

27.2.1 Analog Seismograms

- Older instruments recorded motion on smoked paper or photographic paper.
- Difficult to digitize or analyze with modern tools.

27.2.2 Digital Seismograms

- Modern instruments digitize signals at high resolution.
- Stored as time-series data, enabling easier computation and interpretation.

27.3 Interpretation of Seismograms

27.3.1 Wave Arrival Identification

- **P-wave**: First arrival, fastest, low amplitude.
- **S-wave**: Arrives after P-wave, higher amplitude, slower.
- **Surface waves (Love and Rayleigh)**: Slowest, cause most structural damage.

27.3.2 Amplitude Analysis

- Indicates energy release and potential damage.
- Peak ground acceleration (PGA) and peak ground velocity (PGV) are derived from this.

27.3.3 Time Windowing

- Focus on specific time intervals for evaluating structural response.
- Important for time-history analysis.

27.4 Time-History Records

- A time-history is a plot of ground motion versus time extracted from a seismogram.
- It is essential for **dynamic analysis of structures**, especially in time-domain simulations.
- Contains data like acceleration (m/s^2), velocity (m/s), and displacement (m).

27.5 Seismograph Instruments

27.5.1 Basic Components

- **Sensor/Mass-Spring System**: Detects motion.
- **Recording System**: Converts motion into electrical signals.
- **Timing System**: Provides precise timestamps (often GPS-synchronized).

27.5.2 Strong Motion Accelerographs

- Designed to measure high-amplitude shaking near earthquake epicenters.
- Common in civil engineering for assessing ground shaking under critical infrastructure.

27.6 Seismogram Parameters

27.6.1 Peak Ground Acceleration (PGA)

- Maximum acceleration recorded during an earthquake.
- Used in design spectra and base shear calculations.

27.6.2 Peak Ground Velocity (PGV)

- Maximum ground velocity, critical in assessing potential structural damage.

27.6.3 Peak Ground Displacement (PGD)

- Important for evaluating permanent ground deformation effects.

27.7 Seismogram Filtering and Correction

27.7.1 Baseline Correction

- Removes artificial drift caused by sensor limitations.

27.7.2 Filtering

- **Low-pass filters** remove high-frequency noise.
- **High-pass filters** remove baseline drifts and low-frequency trends.

27.7.3 Integration and Differentiation

- Velocity and displacement are obtained from acceleration using numerical integration.
- Acceleration is retrieved by differentiating displacement or velocity.

27.8 Use of Seismograms in Earthquake Engineering

27.8.1 Structural Response Analysis

- Time-history data used as input for dynamic models (linear/nonlinear).

27.8.2 Site-Specific Ground Motion Studies

- Seismograms used to assess soil-structure interaction, liquefaction potential, and amplification.

27.8.3 Seismic Hazard Analysis

- Historical seismograms help estimate the return period and expected ground motion levels.

27.9 Selection of Ground Motion Records

27.9.1 Criteria for Selection

- Magnitude, distance to fault, soil condition, and spectral compatibility.

27.9.2 Scaling Techniques

- Uniform and spectral matching methods applied to match design response spectra.

27.10 Seismogram Databases and Resources

- **PEER Ground Motion Database (Pacific Earthquake Engineering Research Center)**
- **USGS Earthquake Archive**
- **IRIS (Incorporated Research Institutions for Seismology)**

These platforms provide access to thousands of earthquake records for analysis and design.

27.11 Case Studies

27.11.1 El Centro Earthquake (1940)

- First strong-motion record used in structural engineering.
- Still used as a benchmark for dynamic analysis.

27.11.2 Northridge Earthquake (1994)

- Revealed importance of vertical acceleration components.
- Ground motion led to updates in building codes.

27.12 Limitations and Challenges

- Instrument saturation in very strong motions.
- Misalignment of sensors.
- Signal noise and clipping.
- Inadequate spatial distribution in rural or low-income regions.