01 Seismic Vulnerability Map

The Seismic Vulnerability Map shows the intensity distribution of shaking caused by an earthquake.

Waves transmitted through the ground have regional characteristics and are affected by the stratification* condition of stratums and valleys, low-lying land or terraces. An engineering analysis was held for the entire area of Minato City, and indicated by the scale of seismic intensity.

The seismic intensity indicated on this map is the estimated average size of shaking forecasted by the seismic intensity or the distance from epicenter. As such, shaking may vary according to how an earthquake occurs.

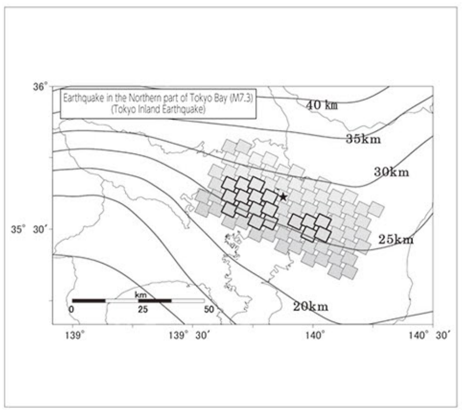
*What is stratification?
On the surface of the earth or on the bottom of the sea, earth and sand, etc. steadily accumulates in layers over many years. Stratums are formed by those materials accumulating in laminae, without interdiffusing.

02 Purpose of Creation

This document was prepared so that shaking intensity could be referred to when newly constructing or renovating buildings aiming towards creating a city well prepared for natural disasters as well as to enhance the disaster prevention awareness of each resident.

03 Forecasted Earthquake

Earthquake in the Northern part of Tokyo Bay (M7.3) (Tokyo Inland Earthquake)



Map 1: Epicenter fault model for Earthquake in the Northern part of Tokyo Bay set on the surface of the Philippine Sea plates in the Special Project for Disaster Prevention/Reduction for Tokyo Inland Earthquake. The "box" is the area where fracture arises in the epicenter fault. The area where an especially large slip occurs is indicated in bold frame.

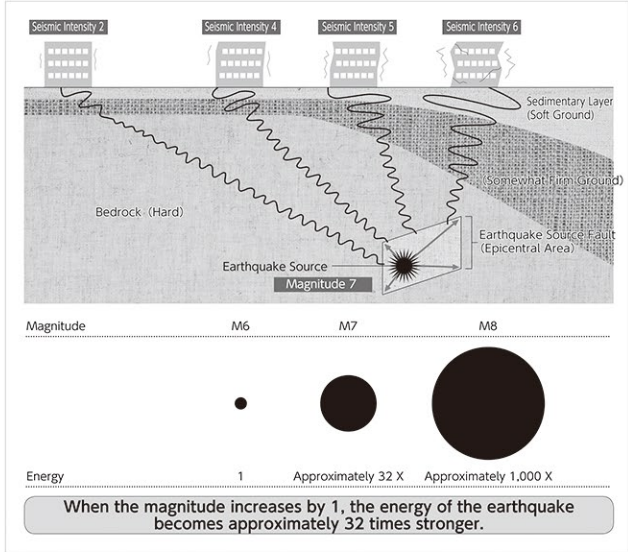
05 Magnitude and Intensity

Magnitude Shows the Scale of the Earthquake

"Magnitude" is the measure showing the size of the fault movement itself arising in the region of the epicenter. The scale (magnitude) of an earthquake is determined by the size of the slippage of the fault surface and the volume of the slippage underground. Magnitude is that which indirectly shows, using the maximum swing of the seismograph, etc., the energy of the seismic wave released by that fault movement.

Seismic Intensity shows the Shaking of the Earthquake

"Seismic Intensity" is the measure showing the degree of shaking at a certain spot. When an earthquake occurs, the seismic wave is transmitted in every direction underground. The size of the shaking in different locations differs due to the way in which that wave is transmitted as the result of the distance from the epicenter and differences in ground conditions, etc. The size of this shaking is measured in those respective locations and the seismic intensity of those locations is determined.



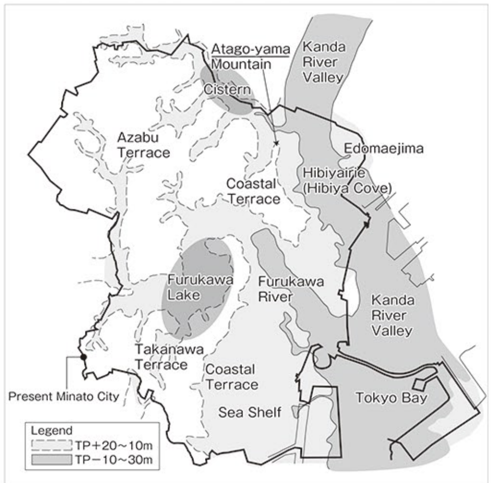
Graph 2: Magnitude and Seismic Intensity

04 Process of Creating the Seismic Vulnerability Map

The Seismic Vulnerability Map uses approximately 8,600 boring data, etc. from Minato City, targeting an Earthquake in the Northern part of Tokyo Bay (M7.3). It also expresses seismic vulnerability in detail by indicating measured seismic intensity (a measurement which provides a more detailed classification of the seismic intensity scale) up to the first decimal point.

- **Subject Earthquake**: Earthquake in the Northern part of Tokyo Bay
- **Calculation Method of Ground Level Shaking**: Based on boring data collected from properties owned by the City and related bodies, a calculation was made of the propensity to shaking on the ground level of each boring site based on a ground response analysis
- **Seismic Vulnerability**: Index Indicated by measured seismic intensity (a measurement which provides a more detailed classification of the seismic intensity scale)
  Example: Intensity 6 upper = intensity 6.0 to less than 6.5
  Reference: Meteorological Agency
- **Map Indication Method**: 50m-mesh indication

06 Seismic Vulnerability and the Formation of Minato City Topography



Map 3 : Old Land Features

Map 3 shows the basal map of the alluvial bottom.

The alluvial bottom is the stratum accumulated from the last glacial maximum (period of the maximum fall of the sea level) approximately 20,000 years ago. The flood plains and riverbeds cut away by rivers or the low wetlands were naturally filled in and built up by pebbles, sand, grain soil and fossil shells accompanying the rise in the sea level.

The difference in shading is the depth of the alluvial bottom.

The light grey enclosed by the dotted line is an area of TP +20 to -10m.

The dark grey area enclosed by the solid line is an area of TP -10 to -30m.

TP ±0 is an abbreviation of Tokyo Peil which is the tidal observation average water level (Tokyo Bay average sea level) based on the Reiganjima watermark established on the river bank extending in front of 2-chome Shinkawa, Chuo-ku. The Japan primary bench mark which is the gauge measurement of height domestically in Nagata-cho, Chiyoda-ku is TP+24.39m. Generally, what is called height above sea level is the height with this Japan primary bench mark as the base point and sea level 0 spot indicated TP24.39m. All boring data in Minato City was calculated and, by making one map, we came to understand the regional characteristics seen from topography and stratum.

Please compare the surface seismic vulnerability map and the the basal map of the alluvial bottom.

In Minato City there are 2 water systems, the Kanda river valley Hibiya inlet and those tributaries (Tougugosho-Tameike-Nishi-shimbashi) and the Furukawa Pond and the old Furukawa river which created the Azabu terrace and Takanawa terrace.

In the glacial age U shaped valleys and V shaped valleys were created and these 2 rivers were submerged in the Shimosueyoshi periods and Jomon periods and soft soil accumulated. As this became a soft stratum in this Area, this translates into greater shaking. The Azabu terrace and Takanawa terrace are less vulnerable to shaking as the ground is firm. We found that the Shibaura and Konan areas are notably vulnerable to shaking. The distribution of this seismic vulnerability is thought to have become like this due to being near the epicenter as the forecasted earthquake is the Northern Tokyo Bay area earthquake.

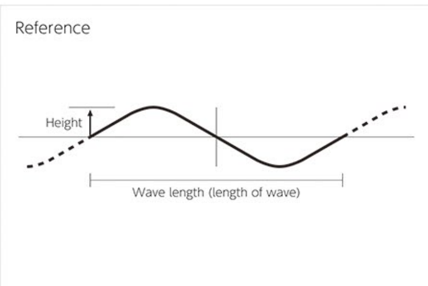
07 How Seismic Waves are Transmitted by Stratums

The destruction which occurs at the epicenter becomes a wave and the seismic wave is transmitted through the ground reaching us on the surface of the earth. The seismic wave is transmitted quickly in certain firm ground located deep underground and is transmitted slowly in soft ground. It gradually progresses towards the surface of the earth and finally reaches the foundations of buildings. (Refer to Graph 5 for a type of seismic wave).

What happens to the Wave based on the Soil Stratification Conditions?

As it is a wave, the seismic wave has the characteristic of being transmitted while curving upwards when being transmitted from firm ground to soft ground. At that time, the flowing wavelength becomes larger and the wave becomes longer.

Additionally, for example, just like in the ocean a wave which hits a quay bounces back, an seismic wave also repeatedly reflected and transmitted many times. In this way it goes and comes back based on the nature of the soil of the stratum underground.



Graph 4 : Height and length of a wave

08 Types of Seismic Waves

At this point, we will provide a little explanation of the types of seismic waves.

Seismic waves are broadly divided into two types. A body wave is transmitted in the earth's interior and a surface wave is transmitted on an extremely thin portion of the land surface and is caused by a body wave's arrival to the land surface.

Within seismic body waves there are P waves (vertical waves) and S waves (horizontal waves). P waves arrive first to the land surface when there is an earthquake and shaking occurs. After that, S waves arrive. P waves are parallel waves in respect to the direction of the transmission of the wave and pushing and pulling occurs due to the breaking up of the ground. S waves travel vertically in the direction a wave transmits, similar to the motion of a rope.

As P wave shaking is not that strong, they are not linked to major damage. However, S waves may cause major damage due to the strength of the wave.

Within surface waves there are Rayleigh waves and Love waves. Although the transmission speed of both waves is about the same, they are smaller than S waves and additionally are the last to arrive due to transmission through the surface layer of soft stratum.

Surface waves have a large shaking amplitude, long cycle and also the shaking time is long.

Rayleigh waves resemble the movement of snakes and are waves transmitted by like drawing an ellipse. Love waves include vertical waves in respect to the wave transmission direction.

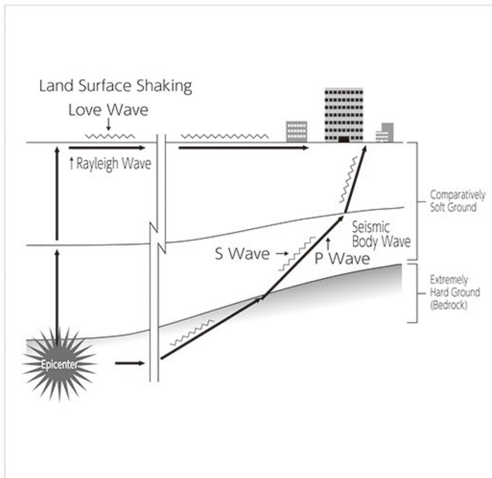


Figure5 : Types of Seismic Waves

Please refer to the 2 waveform charts drawn below.

These are charts which show the calculation of the manner of transmission of a wave with respect to 2 spots - (waveform chart 1) firm ground of a terrace within Minato City and (waveform chart 2) soft ground of an old, buried river.

The same wave of the same earthquake was entered with the consolidated sand as the bedrock of areas with deep ground (bedrock wave shown in the bottom line in each waveform chart).

The form of the surface wave and boundary of each stratum when that wave is transmitted through 4 different stratum moving toward the land surface are shown.

As a result, the height of the wave enlarges more in soft ground than in firm ground.

It is also understood that in soft ground the wave takes a long time to subside.

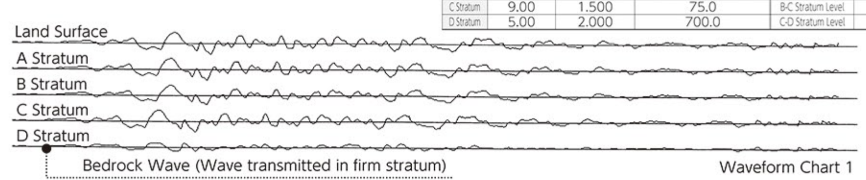
	Magnification of the Surface from the Lowest Stratum	Form of Wave
Firm Ground	2.4	Jolting Shake
Soft Ground	4.0	Rocking Shake

Firm Ground

Jolting Shake

The configuration assuming firm ground is as follows below. Maximum acceleration in the bedrock is 100 (gal or cm/sec²).

Stratification Condition	Stratum Thickness (m)	Stratum Density (t/m³)	Stratum's Shear Wave Velocity (m/sec)	Boundary Plane (Measurement Position)	Stratum's Maximum Acceleration (cm/sec²)
A Stratum	13.00	1.500	75.0	Ground Level	400.1
B Stratum	4.80	1.800	170.0	A-B Stratum Level	403.8
C Stratum	9.00	1.500	75.0	B-C Stratum Level	243.3
D Stratum	5.00	2.000	700.0	C-D Stratum Level	332.9



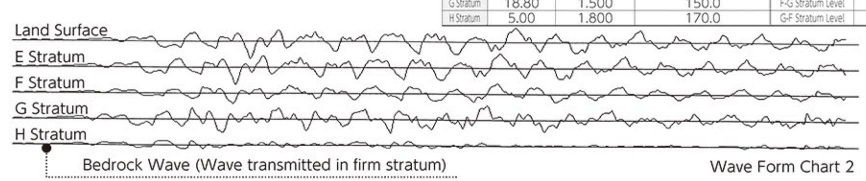
Waveform Chart 1

Soft Ground

Rocking Shake

The configuration assuming soft ground is as follows below. Maximum acceleration in the bedrock is 100 (gal or cm/sec²).

Stratification Condition	Stratum Thickness (m)	Stratum Density (t/m³)	Stratum's Shear Wave Velocity (m/sec)	Boundary Plane (Measurement Position)	Stratum's Maximum Acceleration (cm/sec²)
E Stratum	6.80	1.400	150.0	Ground Level	-248.3
F Stratum	1.40	1.800	170.0	E-F Stratum Level	-248.3
G Stratum	18.80	1.500	150.0	F-G Stratum Level	-229.5
H Stratum	5.00	1.800	170.0	G-F Stratum Level	-251.9



Wave Form Chart 2

09 Q&A Concerning Seismic Vulnerability

Q Are places which are seismically vulnerable dangerous?

A Stratums which are seismically vulnerable tends to be comparatively loose wave (long wave length). Conversely, as stratums which are not seismically vulnerable are under firm terraces, they tend to be jolting-shaking (short wave length).

As the buildings built there have an inherent period in responding to the way they shake (equivalent to the length of wave), the type of shaking differs based on the earthquake which actually occurs.

As the proper period of the building and the dominant period of the ground individually differ, the same level of precaution is required everywhere.