Disaster Mitigation Technologies with the Implant Method

- Disaster Mitigation Projects at Coastlines in Kochi, Japan -

1. Foreword

Every 100-150 years, Nankaido in Southwest Japan is periodically struck by a large earthquake which is known as the “Nankai Earthquake”. Its most recent occurrence was on the 21st of December 1946, known as the “Showa Nankai Earthquake”. The earthquake measured between 8.1 and 8.4 on the moment magnitude scale and involved at least 1362 dead, 2600 injured and 100 missing.

During the earthquake, serious damage to levee embankments occurred in the Kochi city area due to the tremors, liquefaction and tsunamis, resulting in a widespread Inundation in downtown Kochi. The inundation lasted for approximately 1 month as the relative sea level to the land rose due to the ground settlement in Kochi City caused by the liquefaction.

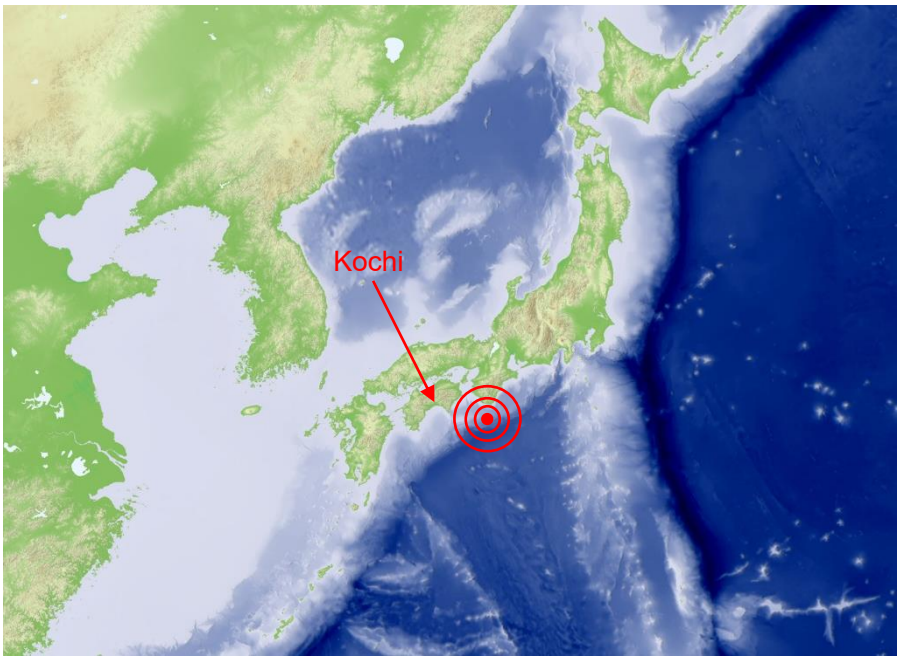

Figure 1: The hypocenter of the Earthquake (Depth of 30km)

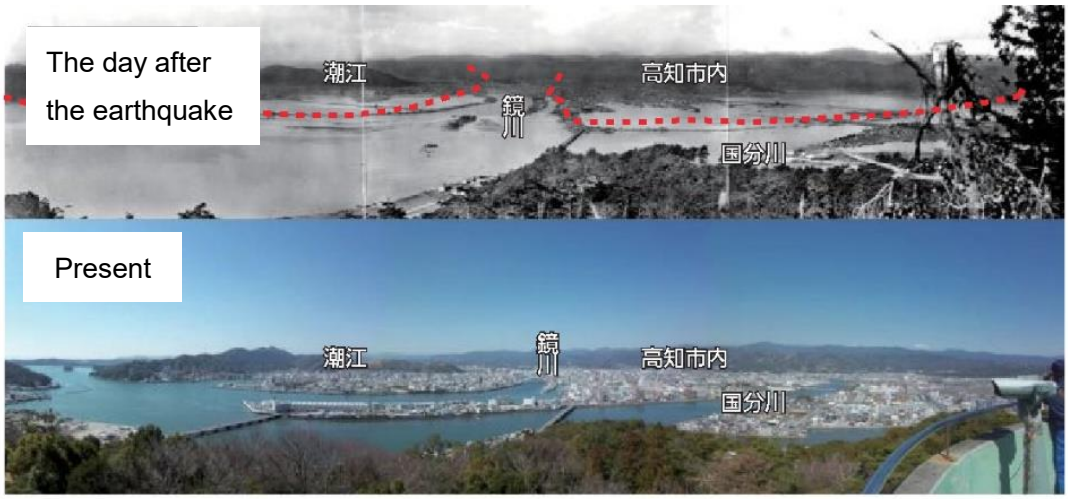

Figure 2: Flooded Kochi city and Present

Japan is located on what is called the Ring of Fire. This is a giant circle around the Pacific Ocean where edges of tectonic plates are slowly moving. This can result in sudden displacement of the ocean floor, which causes earthquakes and tsunamis.

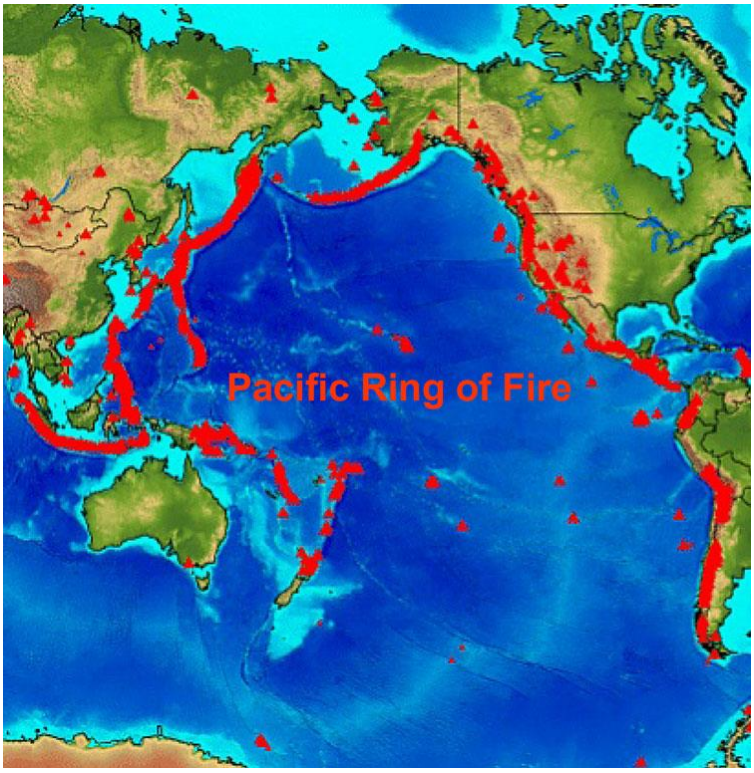

Figure 3: Pacific Ring of Fire

At the Pacific Ocean along the Southwest coast of Japan, the Philippine Sea Plate is slowly being pushed beneath the Eurasian Plate. It is said that within next 30 years, there is a 70% chance of the next Nankai mega earthquake.

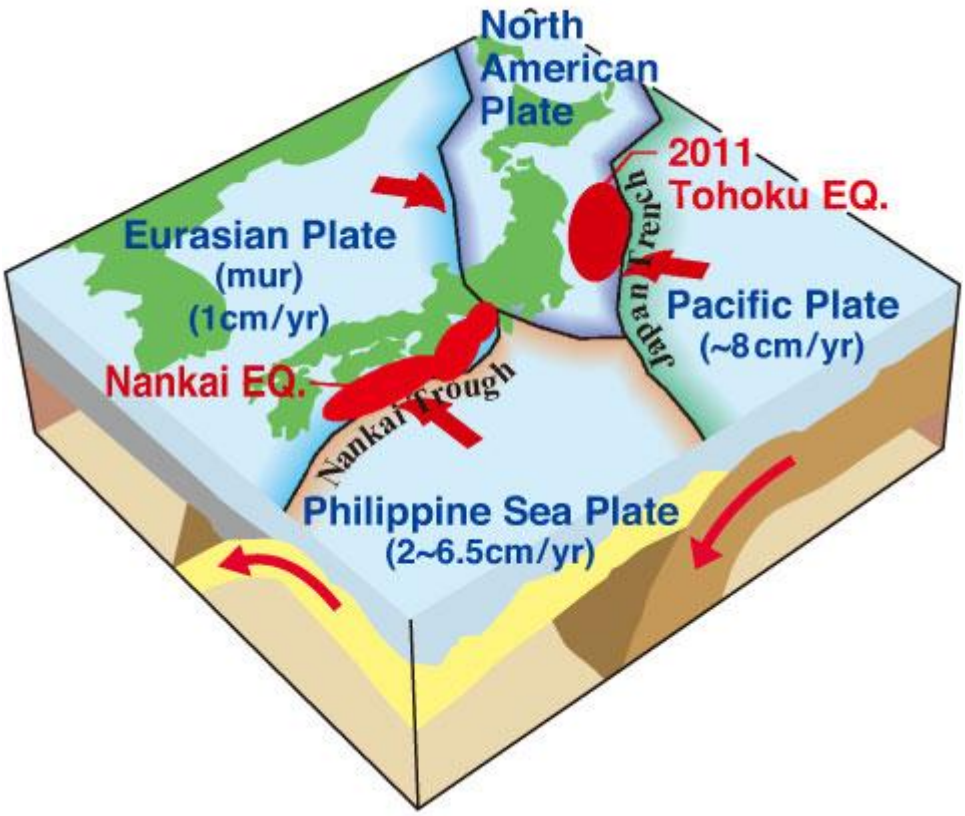

Figure 4: Philippine Plate subducting under Eurasian Plate

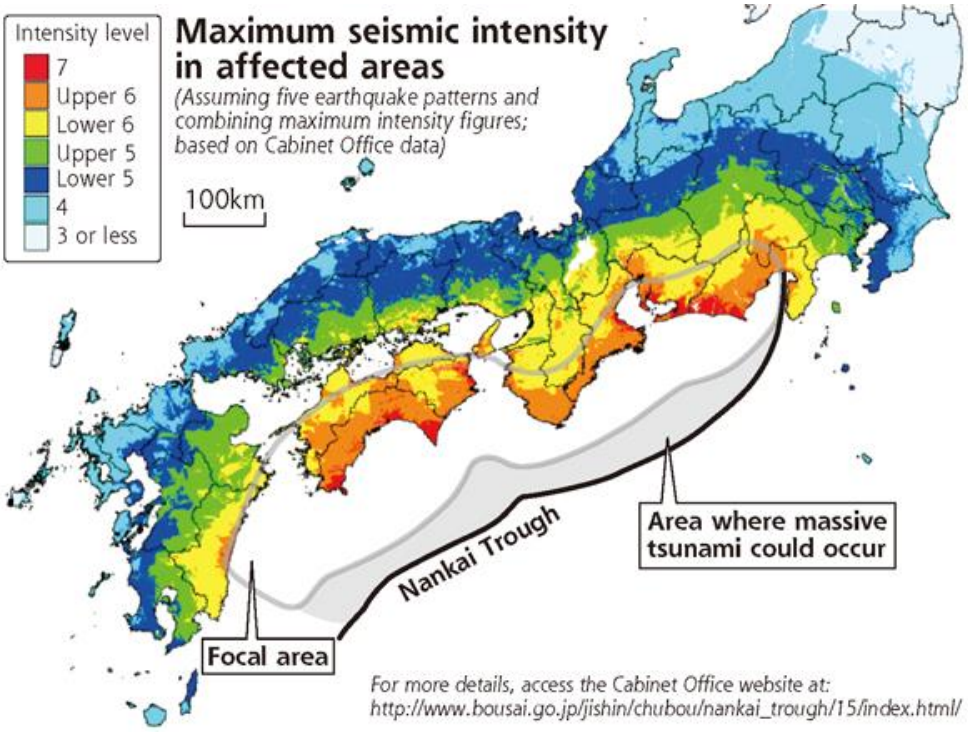

Figure 5: Distribution of Maximum Seismic Intensity (Shindo) in the event of maximum possible Nankai Mega Earthquake

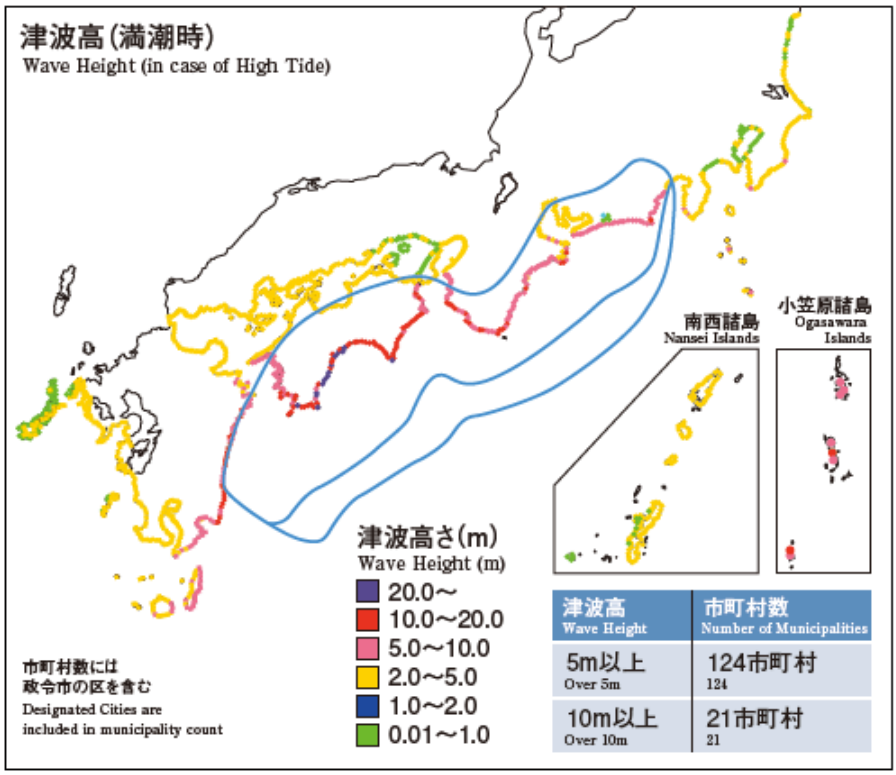

Figure 6: Distribution of Tsunami Wave Height in the event of maximum possible Nankai Mega Earthquake

According to the most recent research, the following damage is predicted in Kochi prefecture in the event of maximum possible Nankai Mega Earthquake.

- The maximum height of tsunamis along the coastal region could be 34m.
- Due to liquefaction caused by tremors, downtown Kochi city could be settled by at most 2m and many levees along the Urado-wan bay could be destroyed or settled, resulting in widespread and long-term submersion of 2,800ha in downtown Kochi city.

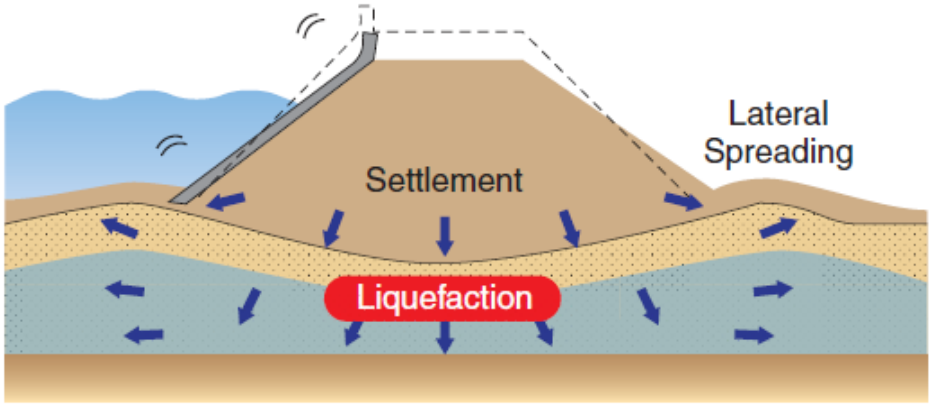

Figure 7: Failure of Levees by Earthquakes

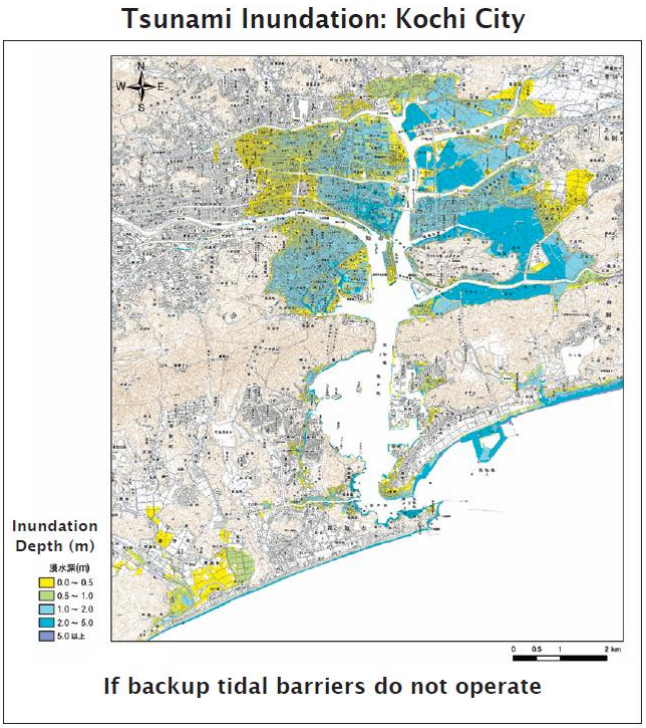

Figure 8: Inundation Prediction in Kochi City

Therefore, Kochi is now bracing itself for the next Nankai mega earthquake to minimize damages. This document introduces disaster mitigation technologies currently planned or being carried out in Kochi.

2. Coastal and Levee Protection Projects

In Kochi, coastal protection projects on the Kochi coast and levee reinforcement projects around Urado-wan bay and neighboring rivers are currently being carried out. This document specifically features these coastal and levee reinforcement projects done by utilizing Implant Structures.

*Implant Structure: Embedded piled foundation installed by the Press-in Method.

2-1. Kochi Coastlines

Approximately 30km of coastlines are slated for reinforcement against tsunamis, where serious damage is predicted when the next mega earthquake occurs. Behind the coastlines, a large population is concentrated and there are many tourist spots and natural wildlife in the area. The Ministry of Land, Infrastructure Transport and Tourism (MLIT) undertook the coastal levee reinforcement as anti-seismic countermeasures in 2012 and so far a 13km stretch of levees were reinforced by the Implant Structure.

出典：国土交通省 四国地方整備局 安芸河川国道事務所「直轄高知海岸南国工区堤防耐震・液状化対策事業」、水産庁「平成24年度公共事業の事前評価書」

Figure 8: Coastal Protection Scheme on Kochi Coast

As mentioned above, widespread ground settlement due to liquefaction is predicted when the mega earthquake hits. This may ruin levees before the tsunami strikes and levee reinforcing criteria were specified as below.

1) Must withstand wave force of cyclic dynamic loads from tsunamis
2) Minimize displacement of levee crest due to liquefaction
3) Minimize noise and vibration during construction
4) Minimize traffic blockage on the road along the coastlines
5) Minimize working space on the beach to avoid disturbing marine wildlife e.g. sea turtles
6) Minimize construction duration and costs

The project steering committee made a comparison between the ground improvement method, pile walls and levee enlargement, as levee reinforcement possibilities. As a result, twin sheet pile walls and tubular pile walls were selected as anti-seismic and anti-liquefaction countermeasures taking account of the above 6 criteria. These 2 methods are utilized in the right place depending on space availability.

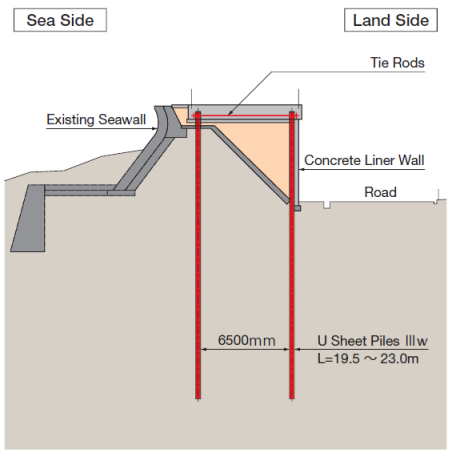

Figure 9: Twin Sheet Pile Walls

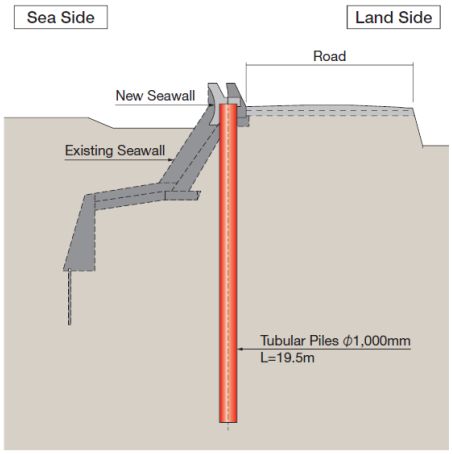

Figure 10: Tubular Pile Wall

Figure 11: Application of Twin Sheet Pile Walls

Figure 12: Application of Tubular Pile Wall

In order to install piles into cobble mixed hard soil which is underlying Kochi coast area, the Press-in with augering method for sheet piles and the rotary jack-in method called the Gyropress Method for tubular piles were selected to overcome the difficult ground conditions.

Hard Ground Press-in Method (The Press-in with Simultaneous Augering Method)

Hard Ground Press-in Method enables piles to be installed into difficult ground conditions such as gravelly soil and cobble or boulder mixed soil without losing the advantages of the Press-in Method. The augering area can be reduced to assist pile installation, minimizing disturbance to the soil strata while eliminating penetration resistance force.

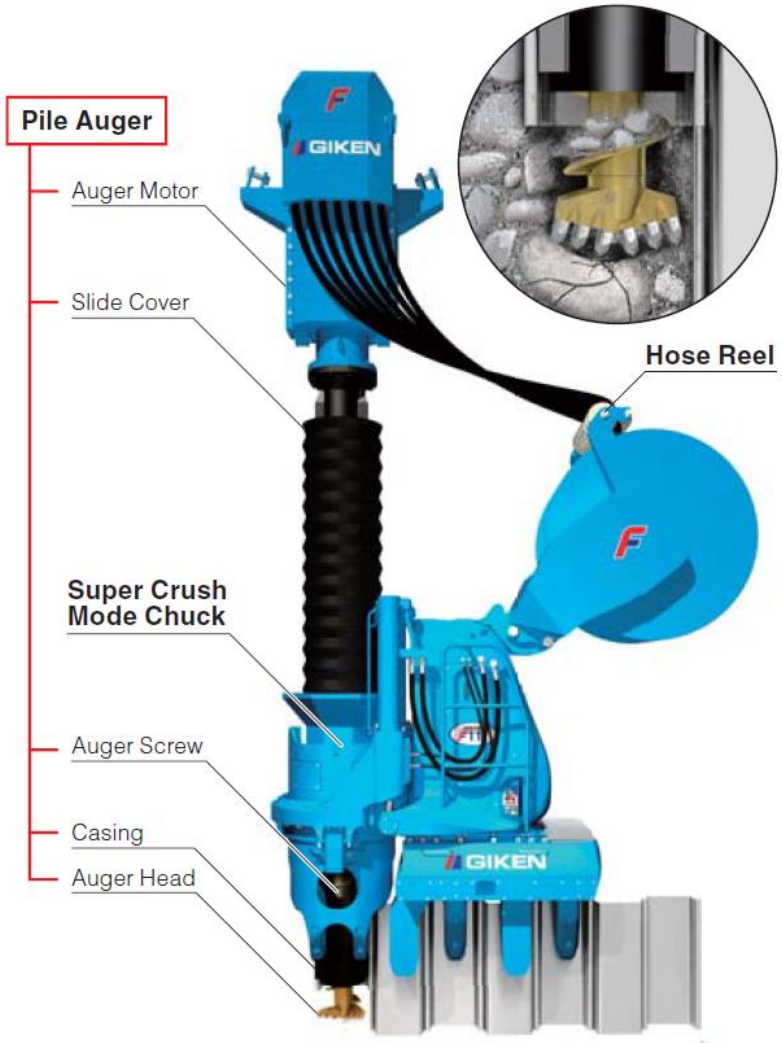

Figure 13: Press-in with Augering Method

Gyropress Method (Rotary Jack-in Method)

The Gyropress Method, in other words, Rotary Jack-in Method utilises combined axial & torsional loading to install tubular piles. With cutting bits attached onto the toe of the tubular piles, this method can install tubular piles through difficult ground conditions, such as gravelly soil, cobble or boulder mixed soil, underground obstructions, or rocks.

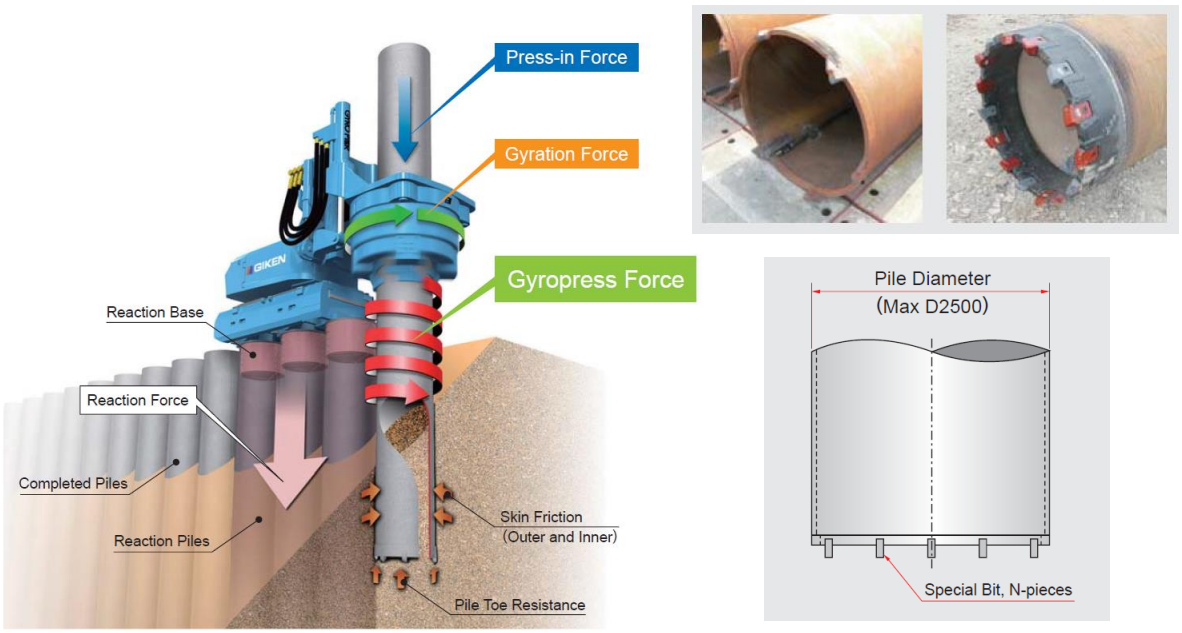

Figure 14: Gyropress Method

2-2. Levees around Urado-wan Bay

Levees around Urado-wan bay have been being reinforced against earthquakes and liquefaction since 2013. The existing levees are reinforced with additional steel tubular pile walls to minimize settlement and displacement in case of earthquakes. In this project, as the project is being carried out in dense residential areas, the Press-in Method is utilized to minimize noise and vibration during pile installation.

2-3. Levees on tributaries of Urado-wan Bay (Kagamigawa River and Kokubugawa River)

As mentioned above, Kochi city suffered heavy damage from a widespread inundation for about month due to the levee failures caused by the previous Nankai Earthquake in Dec 1946. To prevent this from happening again, Kochi prefecture has been carrying out levee reinforcement on the tributaries to Urado-wan Bay since 2009.

Since the crests of a majority of levees are used as roads, the twin wall sheet pile method was applied to allow construction works to be carried out without road blockage. The sheet pile walls protect levees from erosion. Also, by being enclosed with sheet pile walls, risks of liquefaction can be eliminated in the liquefiable layers underlying levees. Thus, the levee crests will remain intact in the event of earthquakes and protect Kochi city from inundation. Furthermore, the levee reinforcement is vitally important to maintain evacuation routes and rescue routes post earthquake.