Building a safe airport that resists natural disasters:
The completion of three major safety projects at Kansai International Airport

Shinya SUZUKI
Member, JSCE
Manager, Planning & Engineering Department, Kansai International Airport Co., Ltd.

Yutaka OKUDA
Technology Group Leader, Planning & Engineering Department, Kansai International Airport Co., Ltd.

Summary of the countermeasures

Kansai International Airport was built five kilometers out to sea on Osaka Bay as a radical solution to the noise problems of Osaka (Itami) Airport. However, while the environmental problem of noise pollution has been overcome, other problems have emerged instead, including ongoing long-term subsidence and the need to deal with natural disasters such as typhoons, abnormal tide levels, and tsunamis. Therefore, our company implemented the following three safety projects from 2000 to 2006:

[1] Installing large-scale rainwater drainage pumps to deal with concentrated torrential rains.

[2] Raising the height of the seawalls to protect the island from tsunamis and high waves caused by typhoons.

[3] Establishing a large-scale underground water cutoff wall to prevent rises in groundwater level due to high tides caused by typhoons, etc.

In this article, we will describe these three measures which have been implemented at Kansai International Airport.

Installing large-scale rainwater drainage pumps to deal with concentrated torrential rains

(1) Why this project was necessary

Under the original structural system, rainfall at the airport flowed from rainwater drains into rainwater drainage pipes, and then out into the ocean by gravity flow. However, with the progression of uneven settlement which has characterized the airport island, the angle of the drainage pipes has gradually lessened, hampering the flow of rainwater into the ocean. Therefore, we have installed large-scale drainage pumps near the opening from the rainwater drainage pipes into the ocean, as shown in Fig. 2, in order to forcibly discharge rainwater into the ocean.

(2) Rainwater pump installation

There were two issues related to installation of the drainage pumps. The first was deciding on the optimal pump capacity with regard to the design rainfall volume, taking economy into consideration. The second was to select the optimal pump configuration and number of pumps, based on economy and ease of maintenance and management, in accordance with conditions at the places where the pumps would be installed.

The first issue was resolved by determining the allowable inundation depth for each area, based on numerical simulations, using unsteady flow analysis with regard to the design rainfall volume.

Regarding the second issue, the optimal format was designed for each place of installation by means of a comparative study including factors such as pump types, costs of pump pit construction, and ease of maintenance and management. For the drainage pumps located near a runway, large pipes must not protrude above the ground because of restrictions related to aeronautical safety. To use conventional large-scale pumps that are vertically oriented, it would have been necessary to build enormous pump pits below ground level, greatly increasing construction costs. Therefore, we modified the permanent magnet synchronous motor, which until that time had only been manufactured in small sizes, and succeeded in reducing construction costs by developing a new, space-saving, horizontally oriented underwater pump, as shown in Photo 1.

The pumps were installed in ten locations with a total of 37 large-scale pumps, having a drainage capacity of 3,300 cubic meters per minute. This capacity is adequate to handle the type of concentrated torrential rainfall that occurs about once every 10 years (20 mm in ten minutes; 55 mm in one hour).

The rainwater drainage facilities are now functioning well, and rainwater is rapidly drained into the ocean.

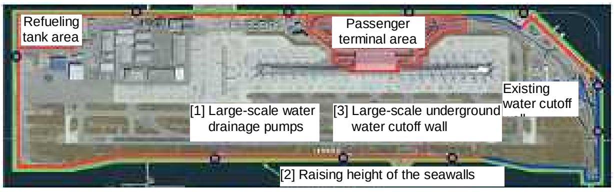

Fig. 1. Locations of safety projects

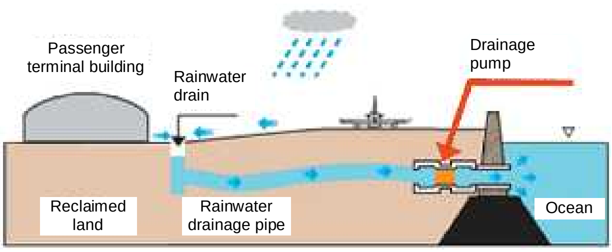

Fig. 2. Diagram of water drainage pump installation

<u>Raising the seawalls to protect the island from tsunamis and high waves caused by typhoons: Summary of the seawall raising project</u>

In 2004, Typhoon 16 and other major typhoons struck the Kinki region repeatedly, causing heavy damage. Kansai International Airport was exposed to the highest tides and waves ever recorded during its 26-year observation history. Waves flowed over the airport's seawalls, destroying a road behind the seawall (Photo 2).

As a countermeasure, the top of the seawall of the first-phase airport island was raised with additional concrete to increase its height (Photo 3).

The airport island is located in a broad ocean expanse in deep water, about 20 meters; so a tsunami arriving here would not be high as a wall, as in coastal areas. In the area around the airport island, the problem would be rather one of high tides than a tsunami. The seawalls were raised in height by one to two meters along a length of about 11 kilometers in order to control high waves that would flow over the seawall, occurring about once every 50 years, at the highest tide level ever recorded for Osaka Bay (thought to be a result of Typhoon Nancy).

Photo 1. New, improved horizontally oriented underwater pump (left); pump pit construction next to the runway (right).

Photo 2. Seawall damaged by high waves (damage caused by Typhoon 16 of 2004).

Photo 3. Construction work to raise the seawalls (left); completed seawall (right).

<u>Large-scale underground water cutoff wall to prevent rises in groundwater level due to high tides caused by typhoons, etc.</u>

(1) Why groundwater measures were needed

Kansai International Airport is built on reclaimed land, consisting of crushed mountain rock and soil surrounded by an environmentally friendly, slow-gradient stone seawall. This gave it a very high permeability coefficient, on the order of 10^{+1} cm/s; and the groundwater level of the airport island rose and fell in tandem with the surrounding tide level. The groundwater level of the island rose at times of high tide levels due to typhoons, or at times of abnormally high sea levels which have occurred nationwide for no clear reason. As a result, groundwater welled up from drains in low grassy areas, and water leaked into the basements of facilities with inadequate waterproofing.

As a radical solution for such problems, an underground water cutoff wall was constructed all around the airport island (Fig. 3).

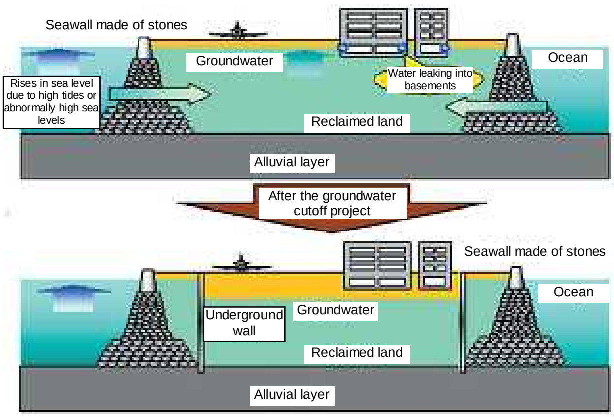

Fig. 3. Diagram of groundwater cutoff project

(2) Summary of underground wall installation

The project was first implemented in two areas that require strict management of the groundwater level: the passenger terminal area and the aircraft refueling tank area. Next, after confirming water cutoff effectiveness in these two areas, a large-scale underground water cutoff wall was constructed all around the entire airport (Photo 4).

Photo 4. Construction work on the underground wall (left); underground wall construction work near the runway (right).

After comparing several methods for building the underground wall, based on aspects such as economy, water cutoff reliability, workability in reclaimed land containing large boulders, and impact on aircraft operations, we selected the full-circle all-casing method. As shown in Fig. 4, casings (1.5 meters in diameter and about 30 meters in length) were driven down as far as the alluvial clay layer, which has low water permeability. The interior of the casings was then excavated and replaced with a mixture of cement, earth, and sand to form pillars in a continuous subterranean structure which forms an underground wall.

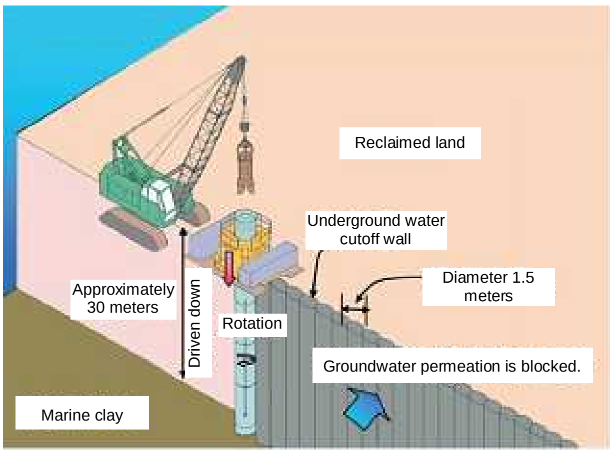

Fig. 4. Diagram of underground wall construction

Since this project was performed under the special conditions of an operational airport, the work was subject to various restrictions for aeronautical safety. Height restrictions on drilling machinery near runways were a particular concern. When the construction machinery is kept below 15 meters in height, the work is much less efficient; costs are higher; and the construction period is prolonged. We used a program called CRM to analyze the risk of an aircraft colliding with an obstacle and then verified the results using flight inspection units, assuming the conditions of actual construction, in order to confirm that the construction work could be performed safely. As a result, we were able to perform the construction work using machinery up to 15 meters in height.

The construction of the underground cutoff wall began in 2004 and was completed in 2006 around the entire airport island. The total length of the wall is approximately 11 kilometers, and it is unrivaled in scale by any other underground wall construction project in Japan.

(3) Effectiveness of the underground wall

Groundwater level gauges are in place at various locations in the airport, and continuous measurements have been taken since before the underground wall was built.

Figure 5 shows groundwater levels before the underground wall was built. Prior to the underground wall, groundwater levels were greatly impacted by the surrounding sea level. They rose and fell in tandem with the tides, although there was a slight time lag compared to tide level fluctuations. After the underground wall was completed, groundwater levels declined and reached a constant level. The groundwater level is about 1.5 meters lower than before the underground wall was built, and its effectiveness has been confirmed. In addition, rainwater that falls on the airport island and penetrates the ground then flows into rainwater drainage pipes and is drained out along with surface drainage, lowering the groundwater level.

As a result of this radical solution, there will be no further rises in the groundwater level in the airport in the case of high tides due to typhoons or abnormally high sea levels, even if further settlement occurs. This is a complete solution to the island's groundwater problems.

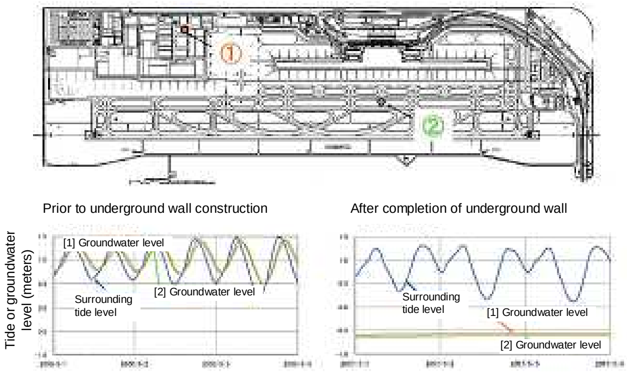

Fig. 5. Correlation of groundwater level with surrounding tide level

Photo 5. Kansai International Airport after the opening of the second runway.

Ensuring a strong, safe airport

Kansai International Airport is surrounded by a harsh natural environment, threatened by settlement, typhoons, abnormally high sea levels, and other problems facing a marine airport, but these problems have been overcome by means of many innovations at its every stage from investigation, planning, and construction to maintenance and management. Fundamental measures to combat natural disasters—installing rainwater drainage pumps, raising the seawalls, and installing an underground water cutoff wall—were completed in 2006, transforming it into a settlement-resistant airport of safety and peace of mind.

The second runway of Kansai International Airport was opened on August 2, 2007, making it Japan's only airport that is up to global standards, having multiple runways of the 4,000-meter class and being capable of 24-hour operation.

In the future, our company will continue to develop the airport further, pursuing the safety, peace of mind, convenience, and comfort which are the basic needs of our customers.