Japan's Increasingly Subtropical Climate:

The Future of Civil Engineering Technology

Feature 2: Implications of an increasingly subtropical climate for civil engineering technology

Chapter 1

Climatic damage and railroads: Railroads too, may operate with an eye on the sky

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Subtropical rain and railroads

Thanks to global warming, Japan's climate is becoming increasingly subtropical with more rain and new rainfall patterns. Indeed, the past several years have seen frequent torrential rains with very high levels of rainfall intensity and total rainfall volume. This is a huge concern for Japan's railroads. They must adjust their train timetables when rainfall exceeds a threshold value, since the earthen structures that support the tracks have limited resistance to heavy rainfall. While increased rainfall is not in itself considered a major safety problem, the rain resistance of individual earthen structures can only be evaluated from past performance in heavy rain. If rainfall continues to increase in volume, breaking records year after year, scientists may be unable to properly adjust the threshold values that determine whether trains can be safely run. Train runs would have to be suspended or delayed during heavy rains, even if slope failures didn't occur, and railroads would not be able to maintain regular schedules.

Severe downpours tend to occur in very small areas. Photograph 1 shows an accident that occurred on August 29, 1988. A conduit passing underneath the tracks at Rokuhara Station on the JR Tohoku Line failed when a heavy water flow caused by record-breaking torrential rains upstream washed out an embankment. As an 18-car freight train entered the station, its lead engine completely derailed. The second engine then overturned to the left of the track, and cars 1 through 9 derailed and fell off the embankment. In this case, the concentrated torrential rains occurred more than 10 kilometers upstream from the railway, so it was not detected by the railway rain gauges on the section of track near the place of the accident. Therefore, train operations were not adjusted appropriately and no disaster security measures were taken. As this case showed, torrential rains must be monitored more closely and over a broader area than ordinary rainfalls.

Long-term changes in rainfall patterns can also trigger unforeseen disasters. Photograph 2 shows the damage that occurred on October 11, 1991 at Kodaira Station on the JR Musashino Line. Rising groundwater caused by an extended rainy spell exerted a buoyant force that lifted the U-shaped semi-underground concrete station structure by up to 1.3 meters. Looking along the tracks, the lifted portion had the shape of an inverted V, topped by the expansion joint of its retaining wall. A large volume of groundwater containing earth and sand flowed up into the station from the ruptured joint, submerging the tracks. Repairs took two months, during which time the Musashino Line did not operate, seriously affecting transportation in the area.

Precipitation in 1991 was heavier than the annual average. On the day of this incident, rainfall totaled 80 mm, which is not a particularly large

volume. However, looking at monthly precipitation levels, the total rainfall in September and October that year was 350 to 500 mm, which is double to 2.5 times the volume of rain in a typical year (150 to 200 mm). Near the scene of the accident was a well for which the water level had been continuously recorded for decades. The water level in this well had risen sharply—nearly 10 meters—during a period of several months before the incident. The relation between this well's water level and the rainfall was calculated using a tank model. The data confirmed that this had been an unusually long rainy spell. The well's high water level on the day of the incident had been reached only about four times in the past 115 years.

Photograph 1. Derailment at Rokuhara Station on the JR Tohoku Line

Photograph 2. Upheaval at Kodaira Station on the JR Musashino Line

Subtropical winds and railroads

Japan's increasingly subtropical climate also means that the country can expect an increasing incidence of severe damage from strong localized winds, including downbursts and tornados. Strong localized winds contributed to a derailment on December 25, 2005 on the JR Uetsu Line. Hurricane Katrina, which hit New Orleans in 2005, inflicted unprecedented damage. Railroads have safety measures in place to prevent accidents due to strong winds. These measures include windbreak fences and rules for adjusting train schedules when anemometers along the tracks detect winds in excess of a certain speed. However, envisioning a subtropical scenario in which all typhoons in the future hit Honshu with the same force that they now have in the area of Okinawa, the current design wind loads for railroad cars, windbreak facilities, and structures may be inadequate in the future. Also, the existing wind monitoring system is unable to detect strong localized winds. Even if it could, it would not be possible to issue an alarm in time to stop the trains.

Paradigm shift in railroad weather monitoring

To cope with an increasingly subtropical climate, Japan will need a weather information system for the railroads that can control train operations in a proactive manner using continuous, spatial monitoring information. The current system issues warnings in a reactive manner, i.e., in reaction to observations of current conditions at a few monitoring points along the railway. A proactive system, however, would consist of a sensor network that would use local radar to remotely monitor meteorological and atmospheric conditions and process and transmit the weather information in real-time. A similar system is already used by the airline industry to prevent downburst-related accidents.

It may seem preposterous at present to imagine that trains would use radar to keep an eye on the sky. However, an early-warning system for earthquakes, a different type of natural disaster, has been in place for the past decade on some railroads.

Japan's Urgent Earthquake Detection and Alarm System (UrEDAS), the world's first early earthquake detection and warning system, instantaneously detects preliminary tremors and automatically activates the brakes on Shinkansen trains before the principal shock arrives. The same proactive approach is also feasible for weather-related disasters. I believe that this could become a reality in the very near future.