# Japan's Increasingly Subtropical Climate:

## The Future of Civil Engineering Technology

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

**Chapter 2**

**Civil engineering materials and climate change**

Sakae USHIJIMA

JSCE Fellow; Doctor of Engineering

Chief Engineer, Customer Service Division, T-net Japan Co.

### Japan's increasingly subtropical climate

Situated off the east coast of the Asian continent, Japan and has a tropical/temperate climate and receives a very large amount of moisture from monsoons. Many of the Ogasawara Islands south of Tokyo, as well as the Amami Islands off Kagoshima Prefecture, and the Okinawa Islands and Senkaku Islands in Okinawa Prefecture, are now all considered subtropical.

Global warming is the reason why Japan's climate is becoming increasingly subtropical. Another factor in climate change is the heat island effect, an urban environmental problem that has recently received attention.

### Urban heat island effect

One cause of the heat island effect is a pattern of wind currents called "heat island circulation." Cities are warmer than the surrounding suburbs because human activities produce heat and the buildings and roads of the "concrete jungle" store heat. This heat causes the air above the city to rise – the heat island effect. The cooler air in the suburbs then moves along the ground into the central city to replace the rising hot air. The hot air above the city then circulates back to the suburbs, where it cools and falls, thus continuing the circulation pattern. Figure 1 shows the total number of hours in 1981 and 1999 when the temperature in urban parts of Tokyo was at least 30ºC on a uniform-distribution timeline. The figure clearly shows the remarkable rise in urban temperatures. Figure 2 shows the average annual temperatures in Tokyo (Otemachi), based on data from the Meteorological Agency. The data indicates a rise of about 3ºC in the past 100 years. Meanwhile, the average annual temperature of Japan as a whole has risen by about 1ºC in the past 100 years, during which time the world's average temperature has risen by about 0.7ºC. Tokyo's increase has been three times the average rise in Japan and four times the average rise worldwide, indicating the magnitude of the heat island effect in urban Tokyo.[1]

The urban heat island effect is related to the growing use of concrete to build urban infrastructure. Figure 3 shows the annual and cumulative production volumes of ready-mixed concrete. The cumulative volume has increased sharply, roughly tripling in volume since 1981. Considering this along with the data in Fig. 1 above, it is clear that the growing use of concrete in urban areas is linked to higher urban temperatures. The heat island effect and the concrete jungle are closely related.

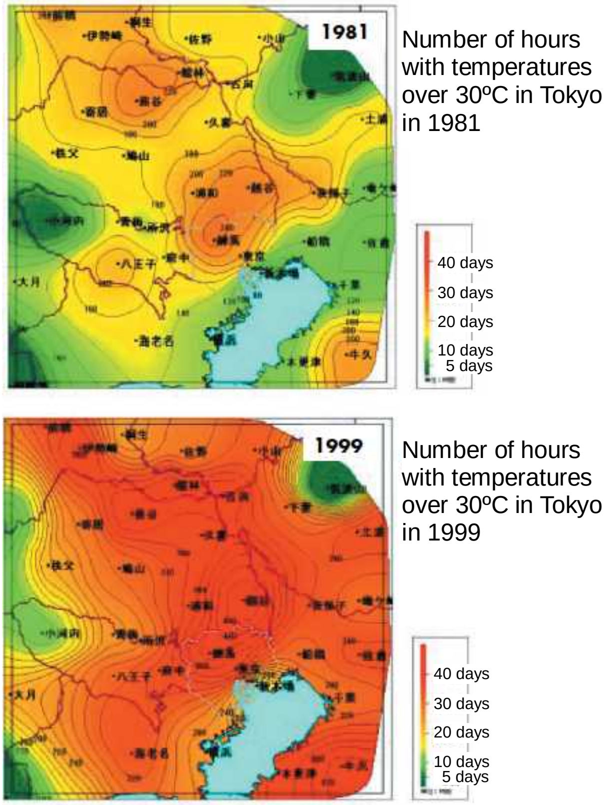


Fig. 1. Average temperatures in an urban area (Source: FY 2000 report by the Ministry of the Environment; an analysis of the current situation and desirable countermeasures for the heat island effect, expanded edition.)

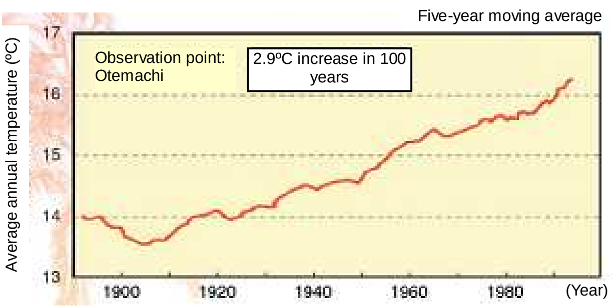


Fig. 2. Changes in the average annual temperature in Tokyo (Based on data from the Meteorological Agency)

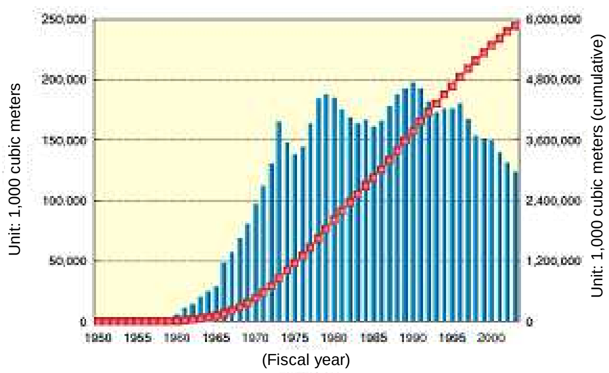


Fig. 3. Ready mixed concrete production volume

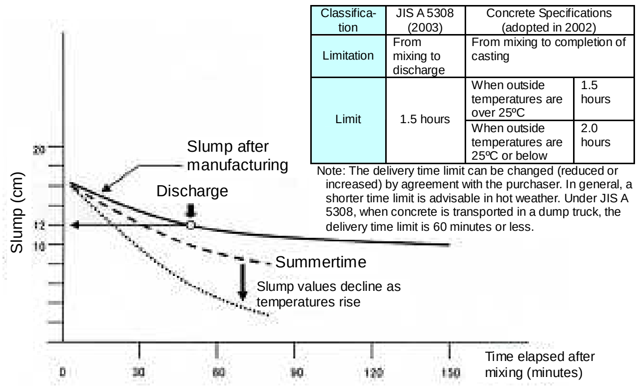


Fig. 4. Slump time after mixing

**Effects of climate change (temperature) on concrete**

Climate change affects both freshly mixed concrete and cured concrete. The workability of freshly mixed concrete is determined by its slump. As shown in Fig. 4, slump decreases over time, decreasing more rapidly as the temperature increases. Certain steps can be taken to control slump, including the use of additives such as a high-performance AE water reducing agent. Freshly mixed concrete must be cast within a certain period, which is shorter when the outside temperature is over 25ºC. If the heat island effect worsens in the future, freshly mixed concrete will have to be transported and cast more quickly than at present.

Table 1 classifies the causes of cracking in cured concrete. Cracking is commonly seen in concrete structures, into factors related to materials, the environment, construction, or structures. In this table, the factors related to temperature are colored. This table not only reflects the wide variety of factors that can cause cracking, but also shows the significant impact that temperature has on construction.

Table 1. Causes of cracking in concrete

| Category | Causes of cracking |
|---|---|
| Factors related to materials | Abnormal freezing of cement |
| | Abnormal expansion of cement |
| | Concrete settlement (bleeding) |
| | Mud content in aggregate |
| | Amount of chloride ions in aggregate |
| | Hydration heat of cement |
| | Contraction of concrete |
| | Use of reactive aggregate and weathered rock |
| Environmental factors | Changes in temperature and humidity |
| | Temperature and humidity differentials at surface of concrete members |
| | Repeated freezing and thawing |
| | Fire and surface heating |
| | Corrosion expansion of internal rebar |
| | Chemical action of acids and of salts |

| Category | Causes of cracking | |
|---|---|---|
| Factors related to construction | Increased amount of cement or water | |
| | Reduced rebar covering depth | |
| | Abrupt casting | |
| | Lack of uniformity in casting and compaction | |
| | Bowed formwork | |
| | Poor layered casting | |
| | Poor joint work | |
| | Vibration and shocks before curing | |
| | Poor initial curing | (rapid drying) |
| | | (early freezing) |
| | Settlement of temporary supports | |
| Structural factors | Excessive load | (bending) |
| | | (shear) |
| | Inadequate cross section and rebar volume | |
| | Uneven settlement of structure | |

## Civil engineering materials can be adapted to an increasingly subtropical climate

*Konkurito Hyojun Shihosho* (Concrete Specifications) is the Bible of concrete at JSCE. By adhering to its guidelines, civil engineering materials and technologies can be adapted to deal with the urban heat island effect as well as the increasingly subtropical climate of Japan. However, in order to resolve the root causes of the problems, it is important during urban planning to create cool islands by utilizing rivers, roadside trees, urban winds, and other factors. Concrete engineers should provide strong support for such endeavors.

## References

[1] Kaya, Yoichi, editor: Environmental Yearbook 2004-2005, Ohmsha, Ltd., pp. 897-899.