STUDY ON RISK AND NEW WBGT ESTIMATION OF ACCIDENT BY HEATSTROKE IN CONSTRUCTION INDUSTRY OF JAPAN

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ABSTRACT

This study is on safety and quality improvement technique for construction and maintenance of building facilities. In this paper, the tendency of accidents in building facilities for the past ten years and the occurrence condition of fatalities disaster by heatstroke in construction industry of Japan is summarized. So it is proposed about the counter measures and experiment for heatstroke.

Keywords: Heatstroke, Construction Industry, Wet Bulb Glove Temperature (WBGT), workplace, Estimation, Accident

INTRODUCTION

Few researches and studies have been conducted in such fields as safety activities, trainings/exercises, danger/risk prevention measures and analysis/evaluation methods for building facilities or the current state of safety/danger in building facilities is not fully comprehended either. Under these circumstances, the purpose of this study is to examine safety and quality improvement technique for construction and maintenance of building facilities. To study the measures of heatstroke is indispensable for labor circumstances in construction and maintenance of buildings. As experiment on the heatstroke in summer we measured environment of some points in Toyo University campus in summer and took date of temperature, WBGT, and so on. The mortality in the construction industry is increasing in comparison with other industries. Also, it has been found out that the number of heatstroke cases has increased due to aging among constructors on one hand, and global warming under the influence of abnormal weather and other factors on the other hand. The rainy season particular to Japan and the summer season also have some impact. It is hoped to take appropriate measures to deal with the situation by conducting on-site environmental research.

HEATSTROKE

Heatstroke is a generic term for physical disorders which occur when the water and sodium balance in the body system fails or the body is no longer able to regulate its internal temperature in a climate of high temperature and high humidity. Its symptoms include dizziness, faint, muscle pains/cramps, excessive perspiration, headache, indisposition, nausea, vomiting, fatigue, despondency, consciousness disorder, convulsion, limb movement disorder, and hyperthermia.

HEATSTROKE-RELATED FATAL WORKPLACE ACCIDENTS

As for the number of deaths caused by heatstroke at work from 1998, the largest number was 47 cases registered in 2010, followed by the second largest of 30 cases in 2013. The number of heatstroke victims in other years stood mostly around 20 According to the data on the occurrence of fatal heatstroke accidents by industry during the past four years (2010-2013), most accidents occurred in the construction industry which was followed by the manufacturing industry.

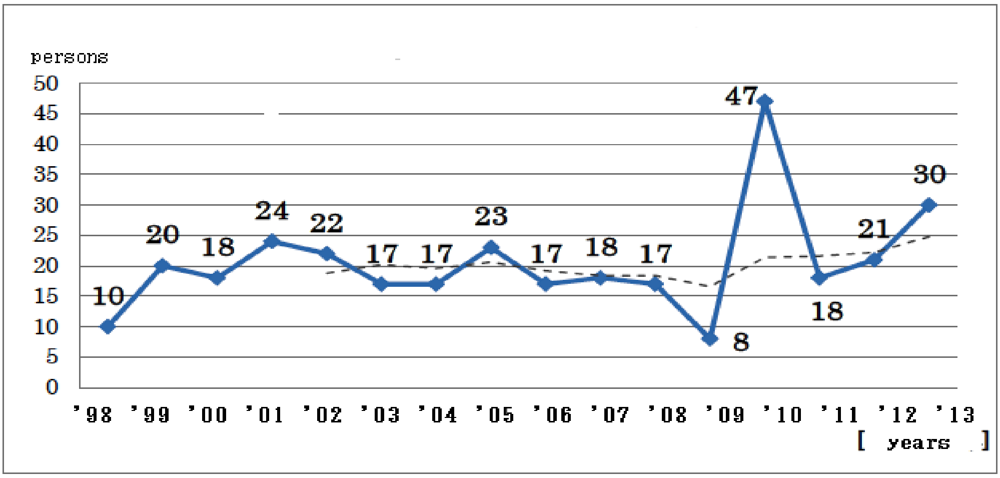

Figure 1. Death toll resulting from heatstroke (1998-2013)

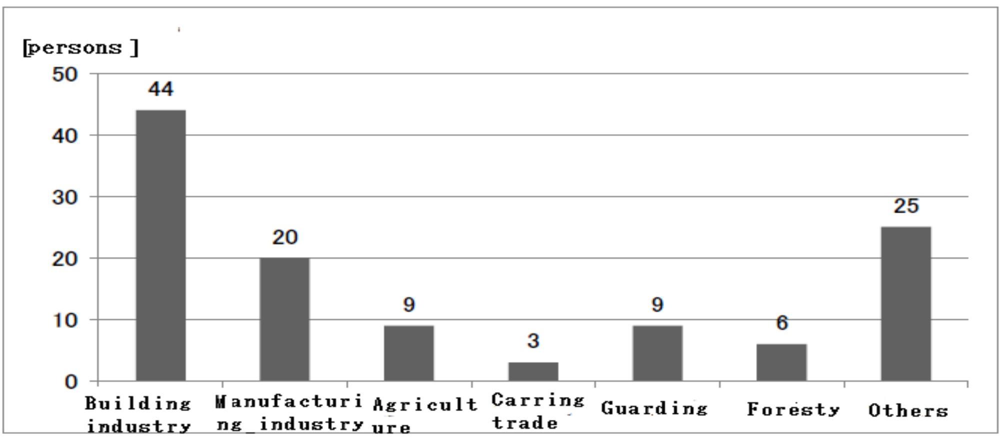

Figure 2. Heatstroke deaths by industry (2010-2013 total)

HEATSTROKE PREVENTION MEASURES

Lowering the wet bulb globe temperature (WBGT)

Efforts should be made to decrease WBGT in the workplace by taking the following measures:

(1) Place a shield between heat source and workers to block the heat in the workplace where a measured WBGT value has exceeded or will possibly exceed its standard value (hereafter, a hot and humid workplace).

(2) Install a roof to easily block direct sunlight and reflection off surrounding wall and ground in a hot and humid outdoor workplace.
(3) Equip a hot and humid workplace with a proper ventilation or air-conditioning facility. The facility installed in a hot and humid indoor workplace should have a dehumidifying function. After water sprinkled in an ill-ventilated hot and humid workplace, caution should be taken not to raise the humidity

BODY TEMPERATURE AND HEATSTROKE SYMPTOMS AND FACTORS

When it is predicted that a WBGT will exceed the WBGT reference value according to the WBGT forecast or heatstroke information service, the WBGT should be measured during work.

(1) Indoors, and outdoors with little solar radiation
WBGT＝0.7×(natural wet-bulb temperature)＋0.3×(black-bulb temperature)

(2) Outdoors with solar radiation
WBGT＝0.7×(natural wet-bulb temperature)+0.2×(black-bulb temperature) +0.1×(dry-bulb temperature) Even if the WBGT cannot be measured, dry-bulb temperature and relative humidity should be referred to in evaluating heat stress.

WBGT AND FOUR THERMAL FACTORS

(1) Four thermal factors are temperature (dry-bulb temperature), humidity (relative humidity), wind speed and radiant heat. By adding other arbitrary evaluation items such as clothing level and metabolic rate, those factors are used to figure out new effective temperature (ET), standard new effective temperature (NET) and predicted mean vote (PMV).

In this case, a black-bulb temperature is expressed in the following Bedford equation. <u>Black-bulb temperature</u> = (mean radiant temperature + (2.37√wind speed × dry-bulb temperature) / (1 + 2.37√wind speed) Equation (3)
Thus, from Equations (2) and (3), the value of WBGT is derived.
<u>WBGT</u> = 0.7 × (natural wet-bulb temperature)
+ 0.2 × (mean radiant temperature + 2.37√wind speed × dry-bulb temperature)
/ (1 + 2.37√wind speed) + 0.1 × dry-bulb temperature Equation (4)
(2) Based on the above mentioned Equation (4), an attempt is made here to calculate the WBGT with tentative numerical values on the theme of “indexes for comfortable working environment.” Factors used in the equation are temperature, humidity, wind speed and radiant heat. In calculating the WBGT,

wind speed is changed as a variable factor, by using a blower in working environment.
Simulation (where wind speed changes)
Dry-bulb temperature: 34.0 °C
Wet-bulb temperature: 28.0 °C
Radiant temperature: 40.0 °C

Figure 3 illustrates the result of an experiment with a wind speed changing from 0 to 13 (m/s) under the above conditions (where a wind at a speed of 13m/s is equivalent to air moved by an industrial blower at close range.)

As the simulation above indicates, a remarkable difference is seen between states of windlessness (0m/s) and light wind (1m/s), but the difference no more widens even though the wind speed increases. Accordingly, it is suggested that an impact of different wind speed on the WBGT is insignificant.

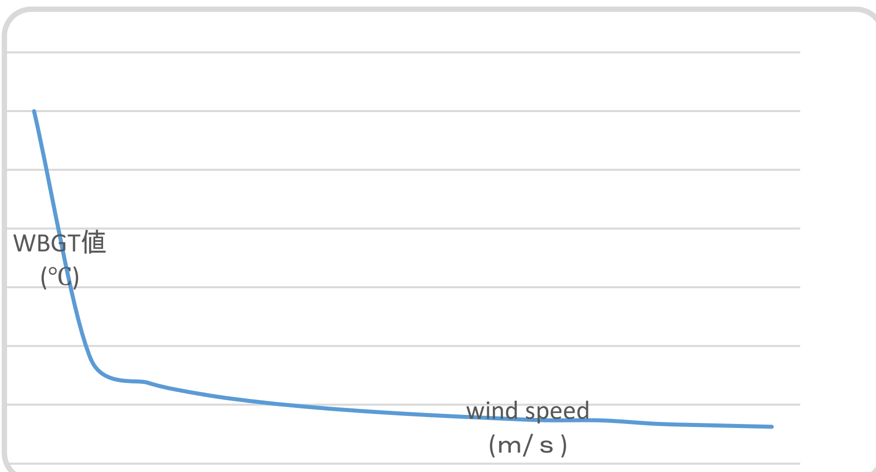

Figure 3. Relationship between WBGT and wind speed

SURVEY IN THE CAMPUS

Outline of Measurement Survey

As Figure 4 illustrates, a measurement survey was carried out at places in Kawagoe Campus, Toyo University (Japan), where distinctive features were detected in the preliminary survey of thermal environment. Table1 outlines the survey conditions. The numbers 1 to 4 in Table 1 correspond to the measurement points and their surrounding environments selected from the preliminary survey, where a measuring kit was installed. The placement of a measuring kit is shown in Figure 4.

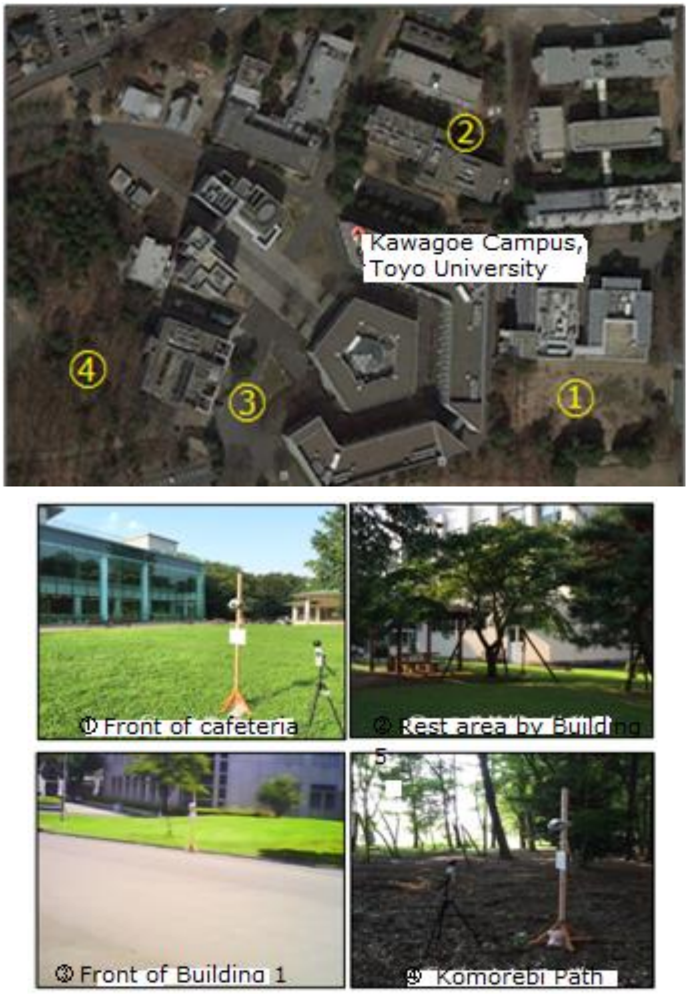

Figure 4. Measurement points

	Kawagoe Campus
Measurement points (surface coverings)	1) Front of cafeteria (grass) 2) Rest area by Building 5 (moss) 3) Front of Building 1 (asphalt) 4) Komorebi Path (leaf mold)
Measurement period	July 10 - July 15, 2015 (6 days) July 30 - Aug. 5, 2015 (7 days)
Measurement items	Temperature and relative humidity, illuminance, ultraviolet radiation radioactive concentration, heatstroke index globe temperature, and sky factor
Height of measurement point	Temperature: 0.1, 0.4, 1.2, 1.5, and 1.8 (m) Humidity: 1.5 (m) Iluminance/ultraviolet radiation: 1.8 (m) Heatstroke prevention meter: 1.0 (m)

Table 1. Outline of survey

Survey Result of Examination

Four places with different surface coverings were selected in the grounds of Kawagoe Campus, Toyo University (Japan), to compare their thermal environments. During the survey period, extremely hot weather continued and therefor reliable data were obtained.

Figure 5 shows that the daytime WBGT values differed substantially among four measurement points: front of cafeteria (MP 1), front of Building 1 (MP 3), rest area by Building 5 (MP 2) and Komorebi Path (MP 4). Those four points are closely examined and compared here.

First, the surface temperature is taken into consideration. The temperature of asphalt surface at MP 3 was nearly 50°C. In the meantime, the temperature of leaf mold surface at MP 4 was about 30°C. As for MP 1, even though the surface is covered with grass, the temperature was 40°C, suggestive of intense direct sunlight. The surface temperature at PM 1 is expected to be low as it is covered with grass. But the place was exposed to direct sunlight with no structures around, so the WBGT once reached a dangerous level.

From 16:30 onward, however, the value rapidly decreased. This may be because the place was shaded by buildings under the afternoon sun. Thus, it was confirmed that the temperature changed greatly at MP 1.

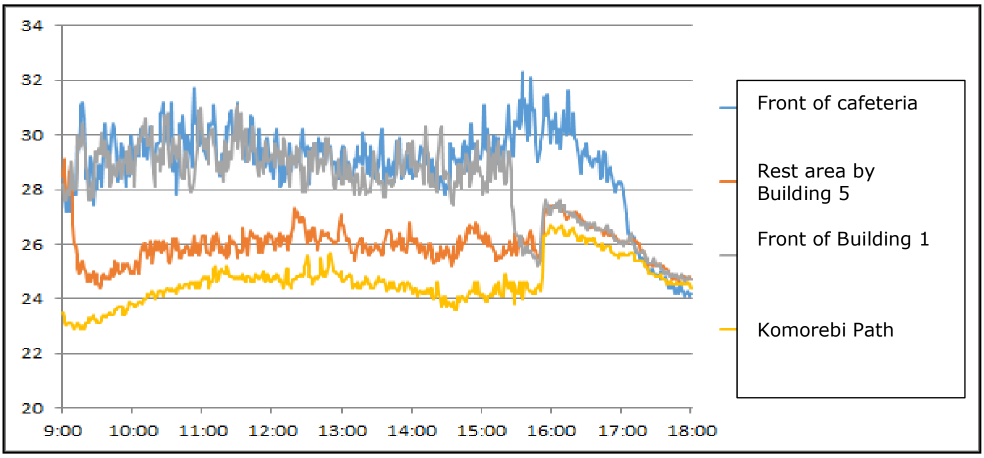

Figure 5. Temporal change in the WBGT at each measurement point (July 13, 2015)

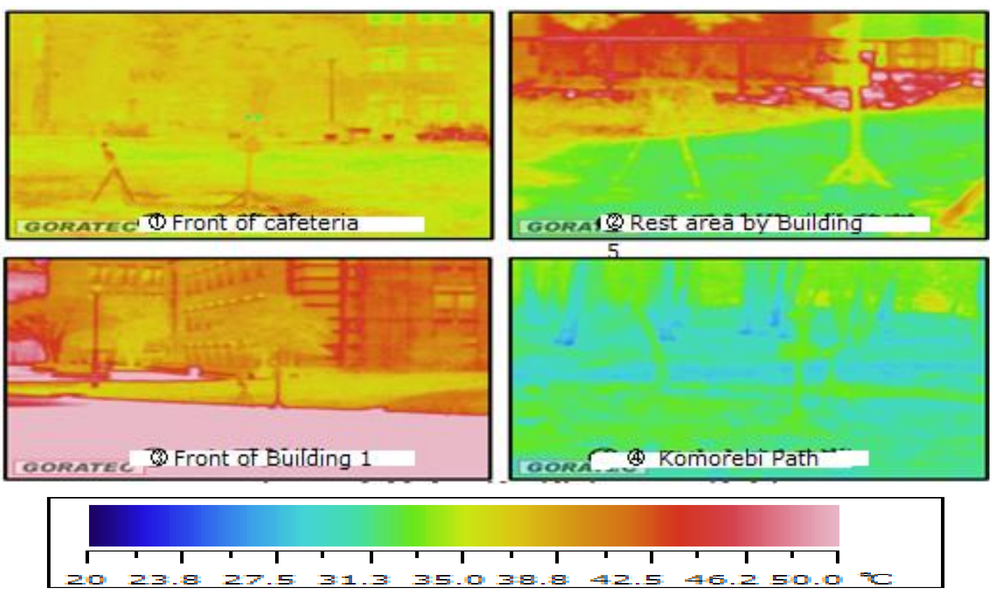

Figure 6. Thermal image at each measurement point (at 14:00)

EVALUATION OF THERMAL ENVIRONMENT UNDER SUMMERTIME WORKING CONDITIONS

Experiment Outline

In this study, an experiment was conducted on heatstroke at a hypothetical building construction and maintenance site. A construction field was reproduced, in which experimental devices were installed. Measurement points surveyed are outlined in Table 2. The data collected on July 22, 2015, are reviewed here as they indicated most noticeable changes.

Measurement points (Surface coverings)	(1) Steel plate (Figure 7) (2) Asphalt (Figure 8)
Measurement items	Temperature and humidity, radiant temperature, WBGT, black-bulb temperature
Measurement period	July 22 (Wed.) to July 25 (Sat.), 2015
Height of measurement point	Temperature: 0.1, 0.4, 1.2 and 1.8 (m) Humidity: 1.5 (m) Heatstroke prevention meter: 1.0 (m)

Table 2. Survey outline

Figure 7. Steel floor

Figure 8. Asphalt floor

Experimental Results on Temperature

Temporal changes in the temperature measured at the 1.8m-high level and at the 0.1m-high level are shown in Figure 9 and Figure 10, respectively. The followings are findings obtained through this survey:

(1) The temperature at the point 0.1 m above the surface is higher than that at the 1.8m-high level all the time in the both asphalt and steel floors. This can be attributed to high radiant heat from asphalt and steel surfaces.

(2) According to Figure 8, the temperature of asphalt floor is higher than that of steel floor after 12:00. This is possibly because the specific heat of asphalt (0.92KJ/Kg・K) is higher than that of steel (0.46 KJ/Kg・K), it kept heat after 14:00 until 18:00.

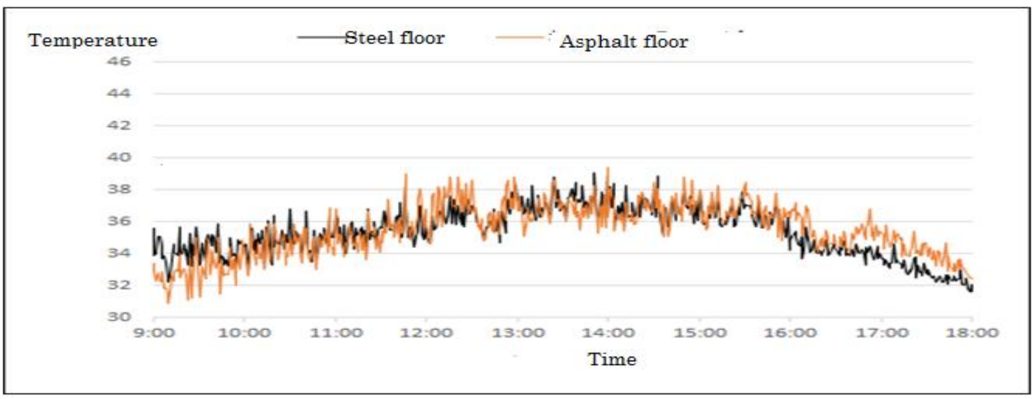

Figure 9. Temporal temperature change(h=1.8m)

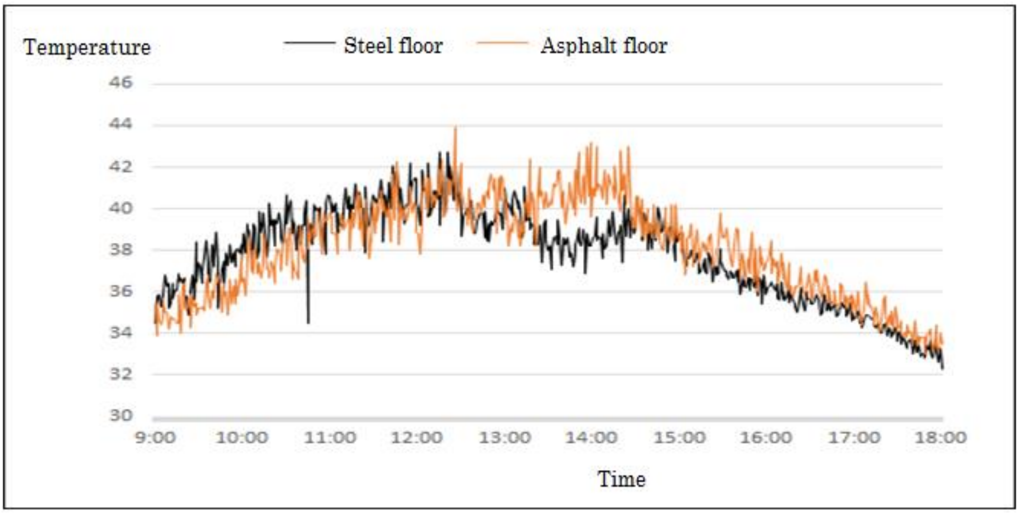

Figure 10. Temporal temperature change(h＝0.1m)

OBSERVATION ON WBGT

No big differences were observed in the WBGT. But as Figure 11 and Table 3 illustrate, the index mostly stayed above the stern warning level. The reason why the WBGT abruptly decreased may be because humidity changed substantially and lowered the WBGT.

EXAMINATION OF EXPERIMENTAL RESULTS

When the temperature is focused on, higher values were found in asphalt. But no big difference were detected between steel plate and asphalt in terms of the WBGT. As Table 3 indicates, however, it should be cautioned that the both cases attained the stern warning level regarding the risk of heatstroke. Therefore, heatstroke prevention measures must be taken as circumstances demand.

Risk level (WBGT)	Intensity of physical activity related to heat illness	**Remarks**
Hazardous (31ºC<)	Any physical activities	An old person is susceptible to heat illness even though he/she keeps quiet. Avoid going out, and stay in a cool room.
Stern warning (28ºC-31ºC)		Avoid going out under a blazing sun. Beware of increase in room temperature.
Warning (25ºC-28ºC)	Medium and heavy physical activities	When intensive physical activity is required, take a rest regularly.
Caution (<25ºC)	Heavy physical activities	The risk is low, but heavy and intensive physical activity might cause the onset of heat illness.

Table 3. WBGT standard level

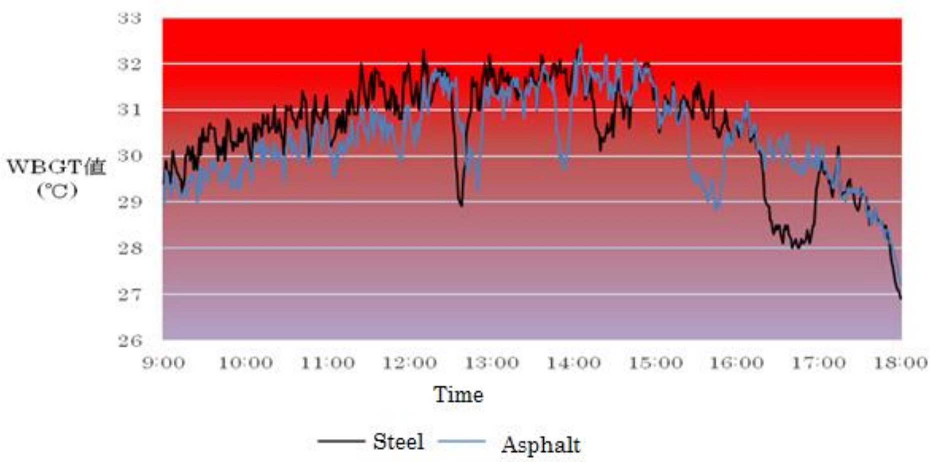

Figure 11. Temporal WBGT change

CONCLUSION AND FUTURE ISSUES

In this paper, the tendency of heatstroke-induced accidents in the workplace was reviewed. Also, an experiment on heatstroke conducted at a hypothetical building construction and maintenance site was reported.

As future tasks, various heatstroke related issues will be addressed through analyses of changes in heatstroke risk and experimental results, on the basis of substantiated data about heatstroke mechanism and prevention measures taken in the workplace by referring to the WBGT standard level.

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