

A Study of Measures to Improve Construction Site Safety Management in Preparation of Heat Waves Caused By Climate Change

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Abstract -Recently, the frequency of natural disasters and the scale of damage are increasing worldwide due to climate change. Heat waves are occurring every year, and the intensity has been strengthened and the duration has gradually increased over the past 10 years. As a result, safety measures against heat waves are essential as damage caused by climate change occurs at construction sites. Therefore, in this study, the relationship is analyzed by comparing the current status of the increase in the number of heat wave days in Korea and the current status of disasters. Afterwards, a survey will be conducted to identify the problems of the safety management system compared to the construction site and to derive measures to improve the safety management of the construction site to effectively respond to the heat wave.

Keywords: Climate change, Heat wave, Safety management, Survey

1. INTRODUCTION

1.1. Purpose of the Research

Recent industrialization has increased the frequency and magnitude of natural disasters caused by climate change. Notably, several never-before-seen climate phenomena are occurring due to global warming and the increase in climate variability (Gertrud Hatvani-Kovacs, 2016). A rise in the average temperature of the earth, an increase in the frequency of heat waves and precipitation on the Korean Peninsula, fine dust, heat waves, and floods are caused by global warming. This endangers the health and safety of construction workers and extends the duration of construction projects. Heat waves occur annually, and their intensity has increased over the past decade while their duration has increased gradually, and heat wave

temperatures are expected to increase even more in the future due to global warming and urbanization (Lee, S. H., 2011).

The average number of heat wave days in Korea has increased from 9.4 days in the 1980s to 15.5 days in the 2010s as the average temperature has risen (KCDC, 2021). In 2018, Korea experienced the highest average maximum temperature and number of heat wave days since 1973. As a result of climate change, the World Meteorological Organization (WMO) predicts that record-breaking heat waves will continue and intensify in the future. Consequently, the significance of systematic heat-related health damage management is increasing.

During the past five years (2017-2021) in Korea, 146 people suffered from heat-related conditions such as heat stroke caused by summer heat waves, and 22 of them (15.1%) died. In the construction industry, as workers frequently work outdoors, heat-related accidents occur annually, and the incidence of heat-related conditions is disproportionately high (MOEL, 2022). As heat-related health damage caused by climate change increases gradually on construction sites that are easily impacted by the weather, safety measures against heat waves are necessary, but the improvement of facilities and systems to prevent heat-related diseases is insufficient (Mohammed N Alshebani, 2014). In this study, we analyse the current state of safety management on construction sites as a result of climate change and look for ways to improve safety management in anticipation of heat waves.

1.2. Methods of the Research

In this study, we intend to analyze the current state of disasters that occur at construction sites during heat waves and identify problems in the safety management system and study improvement plans accordingly. Using statistical data from the Korea Meteorological Administration from 2012 to 2021, we conduct a data analysis on the increase in the number of heat wave days in Korea. In order to comprehend the current status of accidents by industry, statistics from the

Korea Occupational Safety and Health Agency and the Ministry of Employment and Labor from 2016 to 2021 are analysed. For the calculation of heat-related illnesses, industrial accident data for heat syncope (T67.1) and heat cramps (T67.2) were analyzed using the occupational disease classification code "heat stroke and sun stroke (T67.0)," and to prevent duplicate cases of patients with heat illness, the Korea Worker's Compensation & Welfare Service eliminates unnecessary data after the initial treatment (Park. J. C., 2020).

Table 1: Disease classification code and Name of Illness

Code	Name of Illness
R42	Dizziness and vertigo
R55.8	Other syncope and collapse
R99	Other unclear and unspecified causes of death
T67.0	Heat stroke and sun stroke
T67.1	Heat syncope
T67.2	Heat cramps
T67.3	Dehydration-related heat exhaustion
T67.6	Transient heat exhaustion

In addition, risk factors were derived by examining existing literature and accident cases, such as existing papers and Occupational Safety and Health Agency checklists, in order to assess the current status of safety standards for construction site work during heat waves. It was organized into 26 items based on interviews with safety management practitioners and experts, and 50 Korean construction workers were targeted for the sample. Accident experience, safety status, and safety awareness of selected construction site workers are classified and analyzed. The existing occupational health guidelines for heat waves are compared with the management guidelines and basic rules of the Korea Occupational Safety and Health Agency using the survey analysis results. This is compared with construction sites, and problems in the safety management system are identified, and improvement plans are derived to prevent heat-related accidents on construction sites.

2. LITERATURE REVIEW

A heat wave is a natural disaster phenomenon where an abnormally high temperature lasts for several to tens of days and results in loss of life and property. Global warming is the leading cause of the increase in frequency and intensity of heat waves, and since the 2000s, the frequency of heat waves and tropical nights has increased (NDMI, 2017). Human and material losses occur as a result of occupational accidents that occur incidentally during construction work and various production activities (Lee. H. C., 2009). According to Chapter 1, Article 2 of the Occupational Safety and Health Act, the term "industrial accident" means any death, injury, or disease of a person who provides labor caused by structures, equipment, raw materials, gas, vapor, powder, dust, etc., related to the duties, or by work or other

duties. The construction industry is one of the industries with the highest rate of cases, and awareness is growing as a result of recent construction site cases (Kim. D. S., 2019). Nonetheless, as the number of orders and construction projects increases annually, so does the incidence of heat-related accidents on construction sites. As the damage caused by climate change increases at climate-vulnerable construction sites, it is necessary to assess the impact and relevance of climate change to industrial accidents (Kim. H. j., 2012).

As improvement measures, Jung Jae-woo (2007) suggests mandatory installation of safety facilities, stipulation of safety facility installation when building permits, assignment of authority and responsibility for safety management to supervisors, assignment of joint responsibility for construction participants, production and dissemination of simplified specifications, etc., after systematically analyzing the status and problems of safety management. Due to the 2018 heat wave, Park Jong-chul (2020) analyzed the incidence and regional differences of heat-related illnesses and excess deaths. As a result, it was found that the 2018 heatwave had a serious impact on public health. Lee Hyun-chul (2009) conducted a survey targeting workers in order to understand the actual state of safety awareness and to derive measures to improve safety activities. An item-by-item statistical analysis of disaster experience and awareness was conducted in an effort to improve safety management activities by increasing the level of awareness. Yoo Young-hwa (2013) analysed the impact of heat waves on industrial accidents on construction sites and compared a variety of factors with construction site work standards. Problems with the safety management system for heat waves have been identified, along with indicators that can be used for improvement measures.

However, there are insufficient studies on the direct effects of climate change and heat waves on construction sites. Overall, safety measures, improvement measures, and countermeasures for such climate-related factors as temperature, precipitation, and wind, are insufficient, and there are limitations in that professional and specialised safety management solutions are not considered. In light of this, it is essential to investigate professional and specific

safety management solutions for construction accidents. In order to respond to the current state of disasters at construction sites, this study analyses climate change and the current status of heat wave days in Korea. The current state of safety management on the construction site will then be determined through surveys, and measures to improve safety management in preparation for heat waves will be developed.

Table 2: Review of previous research

Thesis title	Author (year)	Content
A study on the improvement of current construction safety management system	Jung. J. W. (2007)	Research improvement plans for safety management in construction projects, systematic analysis of the actual conditions and problems of safety management to ensure safety management on construction sites, and proposal of improvement plans
Analysis of heat-related illness and excess mortality by heat waves in South Korea in 2018	Park J. C. (2020)	Analysis of heat-related illnesses and excess deaths caused by heat waves in 2018, analysis of the incidence and regional variations in heat-related illnesses and excess deaths caused by heat waves in 2018
A Study on the Improving Safety Management by analyzing Safety Consciousness of Construction Labors	Lee. H. C. (2009)	Analysis of safety awareness of construction workers, identification of safety awareness status, and derivation of improvement plans for safety management activities
A Study on Improvement of the Safety Management System to Prevent Safety Accident in Construction Site during Heat Wave	Yoo. Y. H. (2013)	A Study on the Improvement of the Safety Management System to Prevent Summer Heat Wave Disasters on Construction Sites; A Study on the Impact of Heat Waves on Industrial Accidents on Construction Sites; and Comparison of Work Standards and Different Items on Construction Sites

3. ANALYSIS OF TEMPERATURE CHANGE AND STATUS OF DISASTERS

According to the World Meteorological Organization (WMO), the global average annual temperature increased by approximately 1.11 (±0.13) °C in 2021. Due to the warming trend, the average temperature in Korea is rising steadily, and the number of days with extreme heat is expected to increase from 4 days to 59.9 days, a 15-fold increase. Ten

years' worth of average temperature, maximum average temperature, and minimum average temperature are presented in Figure 1. In 2021, the average temperature rose by 1.2°C compared to 2012, while the highest and lowest temperatures rose by 1.4°C and 1.2°C, respectively.

A Study of Measures to Improve Construction Site Safety Management in Preparation of Heat Waves Caused By Climate Change

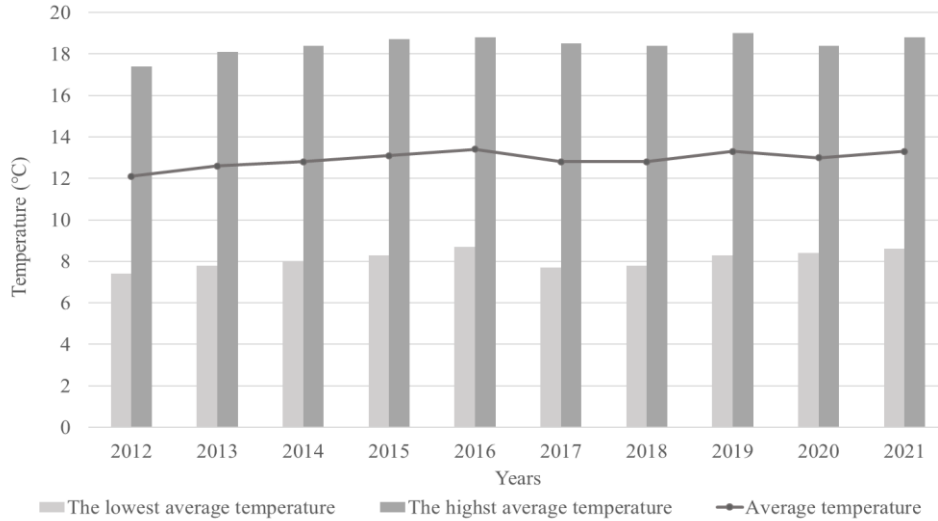


Fig. 1: The average temperature of the last decade

Figure 2 shows the average number of days recorded at 33°C or higher per day or higher. Except for the years 2014 and 2020, when the rainy season was unusually long, the average

number of summer days with a maximum temperature of 33°C or higher continues to rise (KMA, 2022).

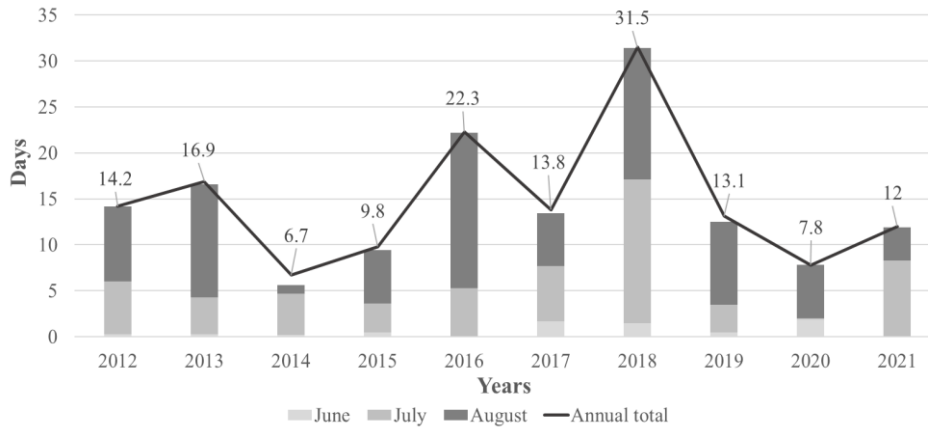


Fig. 2: Heat wave days in the last 10 years

The construction and manufacturing industries account for more than fifty percent of all industrial accidents. The primary focus of the manufacturing industry is indoor work, and facility facilities are established to prepare for accidents caused by high-temperature environments. On the other hand, the external working environment in the construction industry makes it difficult to install facilities to prepare for disasters (Yoo. Y. H., 2013). Therefore, it is necessary to investigate systematic countermeasures that can protect construction site workers from heat waves.

In order to understand the current status of heat-related

industrial accidents in Korea, the data in Table 3 focuses on the number of heat-related illnesses and deaths caused by heat waves. As industrial accident approval data from 2016 to 2021, heat-related illness criteria (name of disease, work characteristics, etc.) were applied. From 2016 to 2021, it appears that the number of heat-related illnesses decreased decrease, but in 2018, when the heat wave was severe, the number of heat-related illnesses increased by about 2.4 times and the number of deaths increased by 3 times compared to the previous year.

Table 3: Status of Patients with Heat-Related Illness from 2016 to 2021

Classification	2016	2017	2018	2019	2020	2021
	Disasters	Disasters	Disasters	Disasters	Disasters	Disasters
Construction industry	15	11	33	11	7	10
Manufacturing industry	6	2	11	3	2	1
Agriculture	2	2	-	1	-	1
Telecommunications	-	-	2	1	-	1
Forestry	-	2	2	1	-	-
Insurance	1	-	-	-	-	-
Other Businesses	11	9	17	3	4	9
Total	35	26	65	20	13	22

In the last six years (2016–2021), heat-related injuries in the construction industry due to summer heat waves accounted for approximately 47.8 percent of all workplace injuries. As shown in Table 4, 88.5% (77 people) of heat-related deaths occurred during the months of July and August, with the

highest number occurring in 2018, when the heatwave lasted the longest (MOEL, 2022). This indicates that the number of heat wave accidents in the construction industry with high frequency of outdoor work is continuously increasing.

Table 4: 2016-2021 Number of Construction Site Fatalities During the Summer

Classification	2016	2017	2018	2019	2020	2021
June	-	-	2	1	1	-
July	6	-	21	3	2	9
August	9	4	10	7	4	1
Total	15	4	33	11	7	10

There is a significant correlation between the number of heat waves reported by the Korea Meteorological Administration and the industrial accident status reported by the Ministry of Employment and Labor from 2016 to 2021. In Figure 3,

the correlation between heat waves and the number of victims can be identified.

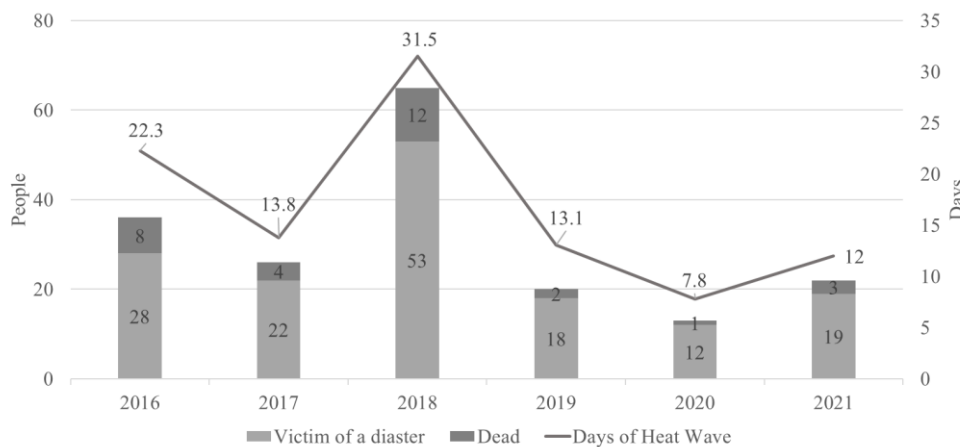


Fig. 3: Comparison of Disaster Status and Heat Wave Days

In 2018, when the number of heat wave days was the highest at 31.5 days, the highest number of injuries and deaths occurred, with 53 injuries and 12 deaths. In contrast, in 2020, when the number of heat wave days was the lowest at 7.8 days, there were 12 injuries and 1 fatality, which was more than four times less than in 2018. This indicates that as

the number of heat wave days increases, the number of victims also increases. Consequently, it is essential to prepare countermeasures against heat waves at construction sites, and a survey uncovered safety management issues at existing construction sites.

4. EXISTING REGULATIONS AND SYSTEMS IN KOREA

We can examine Chapter 5, Section 3 of the Occupational Safety and Health Act concerning industrial accident prevention laws applicable to the construction industry provided by the Korean Law Information Center. Articles 67 and 70 found under the said chapter and section stipulate construction period delays. During the planning, design, and construction phases of construction work, the person placing the order takes precautions according to each category to prevent industrial accidents. If there is a cause of force majeure, such as the occurrence of an event beyond the control of the contracting party, such as a typhoon or flood, the person placing the order for construction work may delay the work. In addition, the construction period must be extended if the construction contractor requests an extension in order to prevent industrial accidents. However, with the exception of government mandates, it is difficult to apply the extension because the reason for it is typically not the responsibility of the contracting party.

As fatal accidents continue to occur due to heat waves, the government and each local government have announced countermeasures.

According to Article 17 of the Standard Contract for Private Construction Works issued by the Ministry of Land, Infrastructure, and Transport, the contractor may request an extension of the construction period if the project is delayed due to heat waves or other factors. In this situation, the contractor must take immediate action, such as extending the contract period and adjusting the contract price, without imposing a delay penalty for the extended period.

According to Articles 23, and 26 of the Ministry of Economy and Finance's "Contract Rules," the construction client may temporarily suspend the construction, extend the contract period for the suspended construction period, and adjust the contract amount if it is determined that the work is significantly difficult due to a heat wave. In addition, it is stipulated that no delay compensation will be imposed if the construction is not completed within a certain timeframe due to heat wave-related difficulties.

In accordance with the "Local Government Bidding and Contract Execution Standards" of the Ministry of the Interior and Safety, work is temporarily halted during heat waves, and the construction period is extended when the contracting party requests a reduction in working hours. When it is necessary to avoid days or times of heat waves, holiday and nighttime work can be requested, and the contract price can be adjusted when the ordering period is temporarily suspended, the construction period is extended, or the working hours are changed.

A survey was conducted to determine the status of construction site safety management in preparation for heat waves. It was conducted for three months, from June to September 2022, and consisted of 26 items that were compiled through interviews with safety management experts and practitioners. Fifty construction workers were surveyed on Korean construction sites. Disaster experience, safety status, and safety awareness of the selected construction site workers were classified and analyzed. The characteristics of each background variable of the survey participants are displayed in Table 6, and the results of the survey analysis and the improvement measures derived from the analysis are provided below.

Table 5: Characteristics of Survey Subjects by Background Variable

Classification	Response	N (%)
Number of years of service (career)	Less than 5 years	6 (12)
	More than 5 years and less than 10 years	6 (12)
	More than 10 years and less than 20 years	5 (10)
	More than 20 years	33 (66)
Occupation	Civil Service	35 (70)
	Construction	11 (22)
	Field agent	2 (4)
	Supervisor, Director	1 (2)
	Site manager	1 (2)
Field	Government level (public construction)	16 (32)
	private and small business sites	5 (10)
	large corporate sites	29 (58)
Working time during heat waves	Less than 8 hours	40 (80)
	More than 8 hours and less than 9 hours	9 (18)
	More than 9 hours	1 (2)
Lunch break during heat waves	1 hour	25 (50)
	More than 1 hours and less than 2 hours	25 (50)
Break time during heat waves	More than 5 minutes and less than 10 minutes	11 (22)
	More than 10 minutes and less than 15 minutes	24 (48)
	More than 15 minutes	13 (26)

	None	2 (4)
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① Safety Awareness

Approximately fifty percent of the fifty workers who responded to a survey regarding the type of support they require most at work during a heat wave selected a flexible working hour system that avoids high temperature hours. Reduction in working hours without wage cuts was the second most frequent at about 28%. In order to avoid the hottest part of the day, it is necessary to adjust working hours to account for the fact that summer sunsets are later in order to avoid the hottest part of the day.

② Disaster Experience

Approximately nine out of ten of the eighteen workers who responded that they had been provided with suitable work clothes (ice vests, cold safety helmets) in preparation for heat waves in the summer on construction sites observed the impact of heat wave preparation. If work must be performed during a heat wave, sufficient rest time and the use of suitable working attire must be recommended. Accordingly, expansion of occupational health and safety management costs is proposed.

③ Safety Status

The most common reason why government measures related to heat waves are not implemented on construction sites is the inability to extend the period (68%), followed by the inability to rest due to contracting practices (20%) and inadequate government supervision (8%). The fact that the construction industry has numerous processes and cannot halt construction during a heat wave due to fixed schedules was identified as a problem. As a potential improvement, proposed are methods for guaranteeing or extending the construction period based on the average number of heat wave days over the past decade.

5. CONCLUSION AND FUTURE WORK

In this study, the relationship between the current status of the increase in the number of heat wave days in Korea and the number of construction site accident victims was analysed, and through surveys, problems with construction site safety management systems were identified and improvement plans were presented. The results are summarised as follows.

From 2016 to 2021, the total number of heat-related illnesses decreased; however, heat-related conditions in the construction industry due to summer heat waves accounted for approximately 47.8 percent of all workplace injuries. In addition, there is a significant correlation between the number of heat waves reported by the Korea Meteorological Administration and the industrial accident status reported by the Ministry of Employment and Labor from 2016 to 2021. In 2018, when the number of heat wave days was the highest, 53 people sustained injuries and 12 people died,

representing the highest number, which was more than four times higher than in 2020, when the number of heat wave days was lowest. This indicates that as the number of heat wave days increases, the number of victims also increases. Consequently, it is essential to prepare countermeasures against heat waves at construction sites, and a survey uncovered safety management issues at existing construction sites. The following are the results of the survey analysis and the improvement measures derived therefrom.

Approximately fifty percent of the fifty workers who responded to a survey regarding the type of support they require most at work during a heat wave selected a flexible working hour system that avoids high temperature hours. Reduction in working hours without wage cuts was the second most frequent at about 28%. In order to avoid the hottest part of the day, it is necessary to adjust working hours to account for the fact that summer sunsets are later in order to avoid the hottest part of the day. In addition, approximately sixteen out of eighteen workers who responded that they had been provided with suitable work clothes (ice vests, cold safety helmets) in preparation for heat waves in the summer on construction sites observed the impact of heat wave preparation. If work must be performed during a heat wave, sufficient rest time and the use of suitable working attire must be recommended. Accordingly, expansion of occupational health and safety management costs is proposed. Lastly, the most common reason why government measures related to heat waves are not implemented on construction sites is the inability to extend the period (68%), followed by the inability to rest due to contracting practices (20%) and inadequate government supervision (8%). The fact that the construction industry has numerous processes and cannot halt construction during a heat wave due to fixed schedules was identified as a problem. As a potential improvement, proposed are methods for guaranteeing or extending the construction period based on the average number of heat wave days over the past decade.

This study analyzed the safety conditions of construction workers and provided recommendations for enhancing the management of construction site safety in preparation for heat waves. However, the survey area is limited and the sample size is small, necessitating future research to analyze workers by geographic region. Additionally, limitations must be supplemented by in-depth research on management measures by construction site size and type.

The analysis of this study's correlation between heat waves and industrial accidents can be used in the future to prioritize heat wave safety management measures, and it is anticipated that this information will serve as the basis for preventing climate-related disasters.

6. ACKNOWLEDGEMENTS

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