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The Effects of Activities and Working Conditions on Fire Accidents on Construction Sites

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Abstract

Accidents on construction sites involving fires do not occur as often as accidents involving falls from height or collapses. However, once a fire accident occurs, there is a high risk of a large number of casualties. Fire on construction sites is affected by working conditions and the types of activities the construction workers are engaged in at the sites. This study aims to identify activities and working conditions at construction sites that are vulnerable to fire, and analyse how they correlate with each other and how they affect the causes and consequences of fire accidents at construction sties. I analysed 40 fire accident reports and listed the situations vulnerable to fire at construction sites considering direct causes, activities, and working conditions. The most dangerous combination of fire hazards can be the heating devices used during rest/sleep in the office/cabin/storage during cold weather. The next most hazardous combination can be sparks arising from painting, waterproofing, insulation, plumbing, or welding/melting work in an underground or confined space.

Keywords : fire, accident, safety, fatality, construction fire

1. Introduction

Fire accidents at construction sites do not occur as frequently as other types of accidents, such as falls from height or collapses. However, once they occur, they can results in large-scale casualties at breakneck speed. The devastating fire tragedy at the Goyang Terminal construction site in 2014 shocked many because it caused eight deaths and 110 severe injuries in the course of only 20 minutes, a relatively short time for fire damage. Although the fire squads arrived immediately and extinguished the fire rapidly, large-scale casualties were inevitable because the fire occurred at a construction site. And this year, a tragic fire accident occurred at a construction site in Icheon that took the lives of 39 people. As there are various combustible materials on most construction sites and potentially ignition triggering works such as welding or melting are frequently being carried out, construction sites are always exposed to the risk of a sudden fire breakout. Significantly, if a fire breaks out in connection with an explosion, the fire could rapidly spread to flammable materials which are hard to put out and bring about large-scale human loss within a few seconds, not to mention the significant economic damage.

Accidents at construction sites are generally affected by working conditions and work types. That is, work types are primarily related to the work trades involved. For example, activities involving welding and melting could be a cause of fire because of sparks

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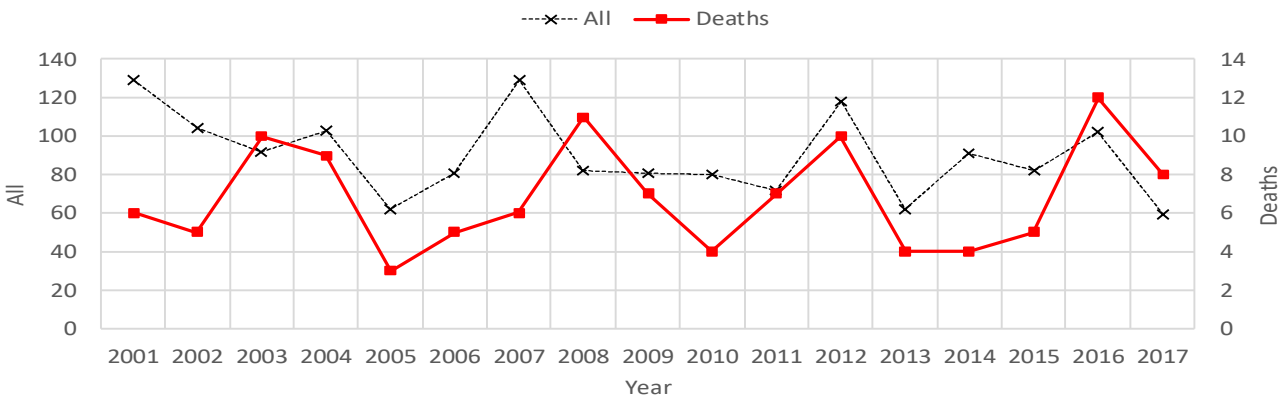

Figure 1. Accidents due to fire in construction site (2001-2017)

and ignition. Work types involving painting and waterproofing could be vulnerable to those sparks and ignition as they employ a large number of flammable materials. On the other hand, working conditions can affect the causes and results of a fire accident. A great deal of the work involved in a construction project is carried out in outdoor spaces, and sometimes at freezing temperatures. For example, in cold weather, heating can cause a fire not only in outside areas but also inside the site offices or cabins. An insufficient alarm and escape system is another risk of a construction fire. If work is carried out in a confined space, there is a high risk of asphyxiation due to failure to escape.

There have been not a few pieces of research regarding construction site accidents. Many researchers have investigated the characteristics and preventative measures for various types of accidents, such as falls from height, slip and falls, machinery accidents, collapses, and others. Still, few have dealt with fire at construction sites. Yao et al.[1] presented experiment outcomes regarding the characteristics of tunnel fires during construction. Liu et al.[2] provided an index system for safety assessment related to fire hazards of construction. Lee[3] provided measures to prevent fire during the construction process of buildings such as fire prevention guide and fire safety education schemes. Ahn[4] performed a detailed study on a polyurethane fire at a construction site. Chun et al.[5] carried out a fire and evacuation simulation for refurbishment works.

Although these researches have been dealt with fire-related matters at construction sites, they did not try to analyze the characteristics of both the work conditions and the fire-triggering activities vulnerable to fire at construction sites.

The purpose of this study is to verify the fire risks of activities and work conditions of construction sites and how they are related to each other and to analyse how they affect the causes and results of construction fire accidents.

For this purpose, this study is carried out by the following steps.

First, this study analyses 40 cases of construction site fire reports[6] and derives fire-related factors frequently mentioned in these reports. Second, these factors are then classified into working conditions, activities, causes, and results. Third, I analyse the effect of those factors on fire accidents. Finally, I will identify the most dangerous fire situations at a construction site by providing the most dangerous combinations of activities and work conditions.

2. Fire at construction site

According to KOSIS(Korean Statistical Information

Service), there have been 1529 casualties reported at construction sites from 2001 to 2017[7,8], including 116 deaths due to fire accidents. Like most common accident types at construction sites, fires at construction sites have not decreased during the past 18 years (see Figure 1). In 2005, the lowest number of casualties was reported: 62 people, including three deaths. But in 2001 and 2007, the highest number of casualties due to fire at construction sites was reported, reaching 129 people. Notably, 2016 saw the highest number of victims of fires at construction sites.

Table 1. Factors related to construction fire

Factors	Number of cases	Categories
Cold-weather	21	climate
Paint/waterproof/insulation	15	activity
Fire with explosion	11	result
Asphyxiate	10	result
Heating	9	cause
Site office/cabin/storage	9	location
Welding/Cutting	7	activity
Underground	7	location
Electricity	5	cause
Burning materials	4	cause
heater (non-electric)	4	cause
heater (electric)	3	cause
Confined space	4	location
Unknown cause	1	

These statistics do not include any specific details of fire accidents such as causes, work conditions, related activities, and other related factors. To investigate more specific fire factors at construction sites, this study examines the fatal accident reports published by KOSHA (Korean Occupational Safety and Health Agency). Of 3869 construction fatal accident reports, as of August 2019, 40 cases involved fire accidents at construction sites. The fire-related factors frequently mentioned in these 40 cases are listed in Table 1.

The factors listed in the table are not mutually exclusive. For example, the most frequently mentioned factor was "cold weather" (mentioned 21 times), which can overlap with other factors. As shown in the third column, the factors can also be categorized into "causes," "results," "climate," "locations" and "activities." Of the fire-related factors, climate condition or cold weather is the most dominant factor highly likely to cause a fire at construction sites, and explosion and asphyxiation are the two major accident types. The following chapters discuss how these factors affect one another.

3. Cold weather

The reports show that heating causes 38% of cold-weather-related fires. In terms of other work conditions related to cold-weather-related fires, 29% of cold-weather-related fires occurred in indoor spaces such as site offices, cabins, or storages. Activities carried out in cold weather fire accidents were rest/sleeping (7 cases), HVAC/plumbing (5 cases), welding/melting (4 cases), painting (2 cases), office work (1 case), and rebar installations (1 case). Activities related to the causes of fire in cold weather are shown in Figure 2.

Of the nine fires caused by heating, only one case has nothing to do with cold weather (see Figure 3).

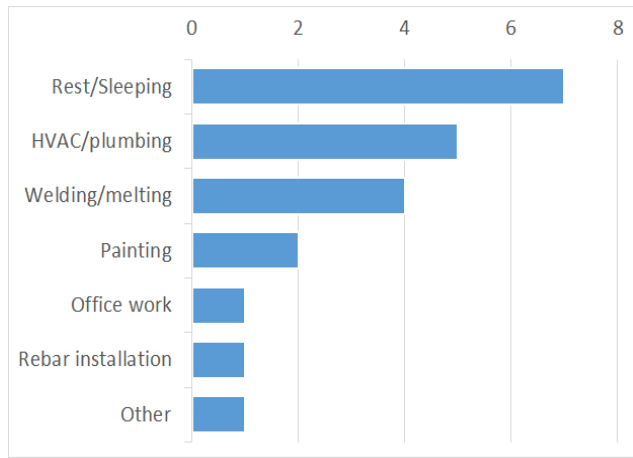

Figure 2. Activities related to cold weather fires

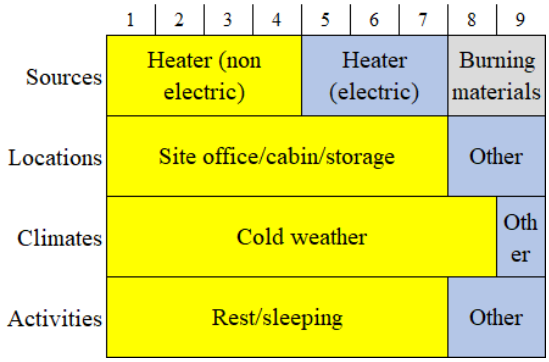

Figure 3. Heating and fire

In terms of heating methods involved in fire accidents, there were four cases with non-electric heaters, three cases with electric heaters, and two with burning materials, which means fire accidents occurred while workers were burning remnants of debris to warm themselves during cold weather. In terms of location, of the nine fires, two cases occurred outdoors, while the above seven cases occurred indoors. In the seven indoor fire cases, workers were resting or sleeping when a fire started. Of the nine cases, two resulted in asphyxiation.

4. Asphyxiation and explosion

Fires in a confined space often lead to deaths of workers from asphyxiation. Of the seven deaths that occurred in a site office/cabin/storage, three died of asphyxiation, accounting for 3 out of 10 asphyxiation deaths due to fire at construction sites. Another three occurred in underground spaces (see Figure 4). The most relevant activity to asphyxiation deaths is welding and melting, which happened in combination with painting, waterproofing, or insulation. Underground spaces are among the most vulnerable to fires, and fires in the underground are likely to cause asphyxiation.

Sparks can cause an explosion. In many cases, a fire can be caused by an explosion, and the key activities related to spark-induced fires are waterproofing and HVAC/plumbing (see Figure 5). These activities employ highly combustible materials. Of the 40 cases of fire caused by an explosion, nine were involved with HVAC/plumbing, and four were involved with welding/melting works. Of the HVAC/plumbing cases, three resulted in asphyxiation, two were caused by burning materials, and three occurred in confined spaces. Three welding/ elting-related fires involved painting, waterproofing, or insulation activities (see Figure 6).

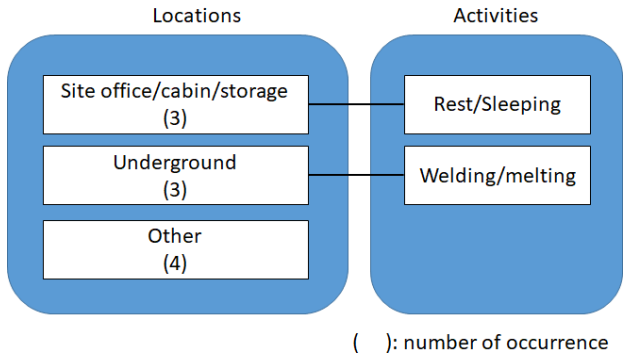

Figure 4. Locations and activities related to asphyxiation and fire

Activities	Number of cases
HVAC/plumbing	
Asphyxiation(Result)	2
Spark(Cause)	4
Burning(Cause)	2
Confined space(Work condition)	3
Welding/melting	
Paint/waterproof/insulation(Related Activity)	3
Fire with explosion(Cause)	1

Figure 5. Spark and explosion

Activities and work conditions	Number of cases
Activities	
Painting	1
Waterproofing	4
HVAC/plumbing	4
Welding/melting	1
Rest/Sleeping	1
Work conditions	
Confined space	2
Underground	2
Site office/cabin/storage	1
Other	6

Figure 6. Plumbing and Welding related fire

Table 2. Causal factors and activities related to explosion

Activities	Causal factors							
	gas leak	spark	bonfire	torchlight	high pressure	electricity	smoking	unknown
waterproofing	2	1		1			1	
plumbing	3	1	1	1				1
painting		1			1	1		
welding		1						
resting			1					
insulation		1						
blasting	1							
resting	1							

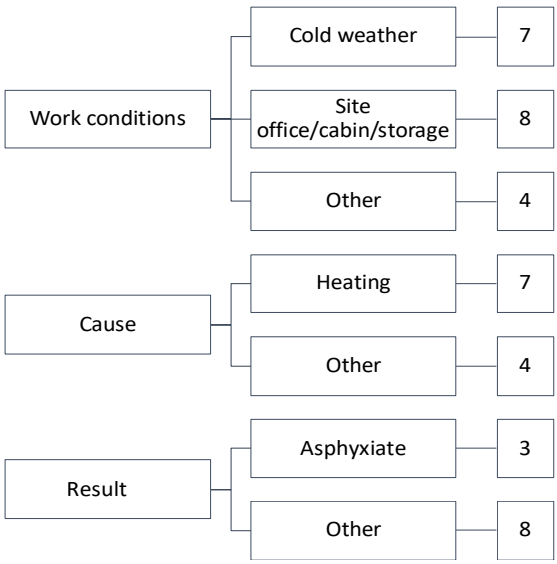

Figure 7. Fires at break time

5. Fires at break time

Fire deaths not only occur while workers are engaged in activity; many occur while workers are sleeping or resting. According to the reports, 11 out of the 40 cases occurred while workers were resting or sleeping. These 11 cases can be categorized, as shown in Figure 7, according to the factors and categories, as indicated in Table 1(note that factors and categories are not mutually exclusive).

Of those 11 cases, seven were related to cold weather and heating, and eight occurred in indoor spaces. Three led to asphyxiation, and only one was started by a spark or explosion. As illustrated in Figure 8, of the types of activities that take place at construction sites, resting/sleeping was ironically the most vulnerable to fire, followed by HVAC/plumbing work(9 cases), welding and melting(7 cases), waterproofing(5 cases), and painting(3 cases).

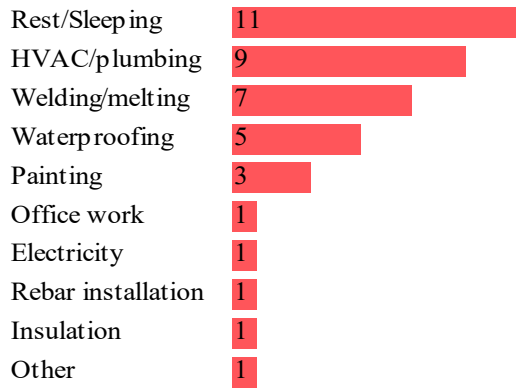

Figure 8. Fire-vulnerable activities

6. High fire risk situations

As discussed above, construction site fires are affected by various factors, such as working conditions and activities, materials, etc. Fires are generally caused not by a single factor but by several factors combined, such as activity, location, and an ignition source. Figure 9 shows how those factors are connected. Each number on the connecting lines indicates the number of occurrences.

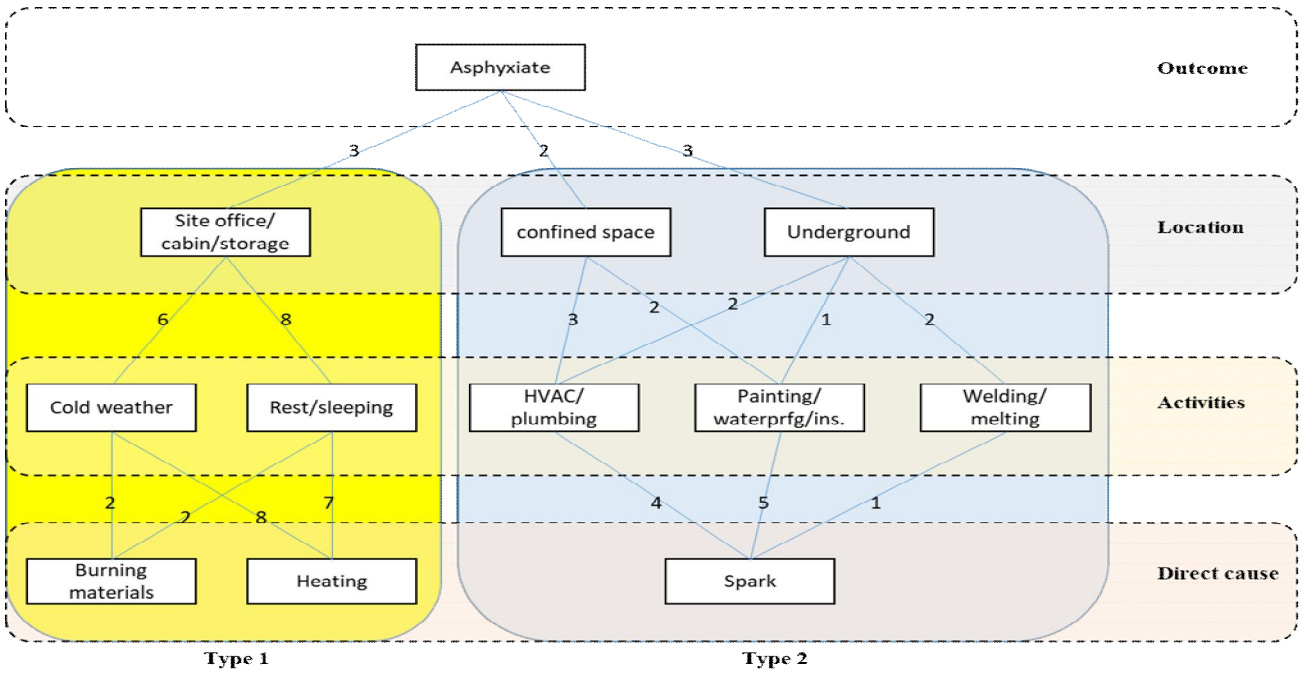

Figure 9. Construction fire factors and their relationships

The most common patterns of construction fire can be categorized into two types: Type 1 and Type 2. To be more specific, Type 1 is the most dangerous combination of fire risk factors, which can be summarized as heating (direct cause) while rest/sleeping (activity) at site office/cabin/storage in cold weather (working conditions). Type 2 is the next most dangerous combination, which can be summarised as spark (direct cause) while painting, waterproofing, insulating, plumbing, or welding/melting (activities handling flammable materials) in underground or confined spaces (working conditions).

7. Conclusions

To verify the characteristics of fire accidents at construction sites, this study examined 40 reports on fire accidents at construction sites and found the following.

Cold weather and heating are the two most critical factors that may cause a fire at construction sites, and most of the indoor fires are related to heating in cold weather conditions. Other frequent factors are “paint, waterproof, insulation,” “explosion,” “asphyxiation,” and “heating.” In a cold weather environment, heating was the most common source of fire, and such fires most commonly occurred during a break, such as while workers were resting or sleeping in indoor spaces. Ironically, site offices, cabins, and storages are the most fire-vulnerable places in cold weather. The most fire-vulnerable activities were HVAC/plumbing, followed by welding/cutting.

Of the nine cases of fire due to heating in cold weather, there were three heating methods involved. Three cases were due to a non-electric stove, another three cases were due to an electric stove, and the remaining two were caused by burning remnant materials in cold outdoor spaces.

The working conditions vulnerable to asphyxiation are site office/cabin/storage and underground space, and the significant related activities are rest/sleeping, welding/cutting, and HVAC/plumbing.

Fires caused by an explosion are mainly related to

waterproofing, HVAC/Plumbing, confined spaces, and underground. The types of activity most vulnerable to fire are rest/sleeping, HVAC/plumbing, welding/melting, and waterproofing, in that order.

In summary, the factors most vulnerable to fire accidents at construction sites are heating in cold weather, especially during rest/sleeping at a site office, cabin, or storage. HVAC/plumbing, welding/melting, waterproofing, painting are the factors next most vulnerable to fire, mainly when carried out in confined spaces or underground.

The findings of this study are expected to help construction managers to control fire conditions and activities vulnerable to fire, to understand their causes and results, and as a result, to prevent fire accidents during the construction process.

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