GU J Sci, Part B, 7(1): 199-209 (2019)

Gazi Üniversity

Journal of Science

PART B: ART, HUMANITIES, DESIGN AND PLANNING

http://dergipark.gov.tr/gujsb

A LITERATURE REVIEW OF FIRE SAFETY IN CONSTRUCTION SITES

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Article Info

Received: 21/03/2018
Accepted: 15/03/2019

Keywords

Construction site, Fire safety

Abstract

Construction projects are exposed to fire hazard in the same way as completed buildings. The risk of fire increases due to the presence of large amounts of combustible materials on construction sites, inadequately educated workers, welding, cutting, drilling processes during construction, and unfinished fire prevention and intervention systems. The aim of this study is to present the results of an analysis of the national and international scientific literature on the subject of "Construction site fire safety" in order to being able to cope with such fires correctly by means of drawing the attention of the authorities responsible, to the danger.

1. INTRODUCTION

Security precautions on construction sites can be defined as the anticipation and prevention of the causes of the accidents that may occur. The reasons for a fire are also very important, as it is in the case of other accidents that may occur. The conditions that may cause a fire during a construction site risk analysis should be well analyzed. It is also important to investigate the causes of construction site fires that have already occurred.

Reasons such as the easy combustion of products and materials, sparking productions, the employment of a large number of untrained persons, the incomplete production of electrical, mechanical and fire fittings, and the establishment of facilities for temporary accommodation are the factors that increase fire risks onconstruction sites.

Good reaction and perception times are often sufficient for workers to intervene in the more common and unreported site fires, in contrast to sudden accidents such as falling from a high altitude and injuries from material fall. For this reason, the number of worker deaths and injuries in construction site fires is lower than that associated with other types of accident. However, the incidence of fires that are not extinguished in time is increasing rapidly, and cause serious financial loss. In the United States alone, in 2014, there were financial losses of $187 million in major construction fires.

When examining the existing special specifications and regulations, the precautions which must be taken for fire safety on construction sites can be listed as follows:

- Foam fire extinguishers of adequate capacity shall be installed in places where they will be needed, and operating instructions will be added to the fire extinguishers. These devices will be checked regularly.
- Bare cables will definitely not be used for transporting electricity to certain construction site locations. If cables are used, any joints will be absolutely insulated. Lines will not be used without grounding.
- For lighting, tools such as open flame lamps and candles shall not be used. If there is no electricity available, lighting means such as a hand lights or a flashlights shall be used.

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- Indiscriminate burning of materials on the part of the workers at the construction site without the permission of their superiors will not be permitted.
- Worker accommodation such as tents incorporating inflammable materials is not permitted. The accommodation will have sufficient exits for the number of people and the size of the accommodation. Heating systems in the accommodation should be ones that do not involve a fire risk.
- Flammable chemicals and liquids, oxygen cylinders and similar materials that can easily be ignited, causing fire and explosion, shall be stored in places where there is no risk of fire. These storage areas should be indicated using fire safety signs. Fire must not be permitted adjacent to such storage areas.
- Smoking will be prohibited outside designated smoking areas. These areas will be isolated from flammable substances in the building area.
- Fires relating to electrical installations should be avoided. Where there is a risk of fire such as in the case of electric panels, fire extinguishers should be provided.
- Personnel responsible for the avoidance of fire risks should be well informed, and such staff must be informed of the action to take in the event of a fire. The location and number of fire extinguishers should be determined. These must be prepared and hung in clearly marked places throughout the construction site. In addition, phone numbers (fire brigade, police, hospitals, etc.) to be called in case of emergency must be clearly posted. If there is an emergency meeting area, this would be the best place.
- The document cabinets located in the construction site offices should be made of fireproof steel. In addition the description "First priority to be rescued in the event of fire" must be written on the cabinets.
- Water storage facilities with at least 2 ton capacity will be build on the constructionsite.The water storage facility will be made ready for service with a fire hose, union coupling ,an intermediate faucet, as well as the necessary capacity. If the water cannot flow with the help of gravity, a pump will be installed.
- Fire detection, warning and extinguishing systems should be installed as soon as possible in the building.
- The authorities will be notified before the start of any work on the construction site that increases the risk of fire, such as welding. During this work, a fire observer will be assigned, and this observer will continue to observe the application area for half an hour after the work is finished. In addition, at least one fire extinguisher will be ready in those areas where hot works occur.

In this article, national and international research into fire safety precautions in construction sites have been evaluated, analyzed and presented.

Fig. 2 The architecture of a smart product. Copyright © 2017 Güneş and Güneş.

Indeed, one must consider of those components distributed along a continuum, which has gray multidisciplinary zones, such as mechatronics. In smart products, at one polar of this continuum are crowded by virtually connected world and services, and at the opposite end are bunched by physical world and end-users. At the mid-region of the continuum, smart components are located between these two poles, which are aiming to combine the virtual and the physical, and vice versa. If the reader keeps this concept of the continuum in mind, the gray zones of the smart product continuum refer to a space of cooperation, competition, collaboration, and also conflict between professions. By explicitly conceptualizing the two poles and the continuum in between, the coherence of the cooperation of professions is dramatically increased. For this reason, the contributing professions in the smart product design and their relationship to each other deserve a separate academic interest. If a smart product offers something more from its embedded technology, however, this can only be achieved by appropriate product design, its users will deliver some real value. Smart products have a lot of features differs them from other non-smart ones. Each feature introduces new sets of challenges and opportunities when designing products.

1.NATIONAL RESEARCH

The determination of classes of fire with regard to building materials and the limitations in terms of their use in buildings is important for the prevention of fires on construction sites. Building materials stored on construction sites before being used in the building process, can only be kept in a suitable form to prevent fire when the reaction to fire of classes of materials is known.Demireland Altındaş in their studying 2006 [1],analyzed the Construction Products Directive (89/106/EEC) published by European Union to eliminate different approaches among the Member States.

Although it is emphasized that precautions should be taken against the risk of fire, there is no clear information on the nature of the precautions in Turkey's "Occupational Health and Safety Regulation in Construction Work"[3] dated 5/10/2013 and numbered 28786, to be applied in construction works which are within the scope of the "Occupational Health and Safety Law" dated 20/6/2012 and numbered 6331.

In Turkey, the Occupational Health and Safety Campaign in Construction was introduced by the General Directorate of Occupational Health and Safety in 2006. A checklist of informative activities on "Occupational health and safety in small construction sites" was published as part of this campaign. In this is was stated that sufficient numbers of fire extinguisher devices, proper escape routes and other fire safety measures should be controlled on site [4].

Within the framework of the Project for the Improvement of Occupational Health and Safety Conditions in Turkey (ISGIP), financed by the European Union and the Republic of Turkey, the risk assessment in the guidelines prepared by the General Directorate of Occupational Health and Safety [5] for the construction sector, and by the Occupational Health and Safety (OHS) organization, a method is suggested for monitoring the situation found on construction sites. In the prepared control list, article 7 is used for examining fire precaution-related controls.

Inspections were carried out by the Republic of Turkey's Ministry of Labor and Social Security Labor Inspection Board[6] in 2006, aiming to assess the OHS (Occupational Health and Safety) conditions in construction sites, and to determine the deficiencies. As a result of inspections carried out on 2,680 construction sites in fifty-five cities, the employers and responsible person were informed about the deficiencies. Subsequently, second phase inspections were conducted in the same construction sites with regard to the control of these deficiencies, and for the detection of new deficiencies.326 deficiency in terms of first aid and fire fighting teams on the construction sites, and 254 flaws in the fight against fire detection and fires were identified. In the second phase of the inspections, these numbers had dropped to 95 and 81 respectively.

A new system has been proposed to determine the work safety performance of construction sites in the study by Metinsoy and Mungen [7]. The purpose of this work was to propose a new method of determining the general work safety performance of a worksite by evaluating the work safety management performance and the work safety performance in the field, in order to increase work safety during construction. The study is based on the creation of software that has the ability to evaluate the work security management performance and the work safety performance of the contractors, working on the basis of a fuzzy logic approach entitled SME (Business Security Management Evaluator).When safety performance was considered in the monitored construction sites, fire safety exhibited the second lowest performance level after the prevention of accidents due to falls from height. It can be said that fire precautions on construction sites are among the least commonly applied measures.

In his study of the residential fires resulting from the electrical installations, Şengöz [8] indicated that, between 2005 and 2010, the fire brigade in the province of Antalya reported that there were 7 electricity-caused construction site fires. Although 6 of these fires involved the risk of electric shock, it was noted that the intervention was made with water.

In the seminar on "Construction Site Fires and Occupational Health Safety" organized by the Istanbul Provincial Representative of the Turkish Institution of Mechanical Engineers in 2012,a presentation was made by Kılıç [9] on "The fires occurred in businesses and construction sites 2012, their causes, and could they been prevented?"

Kılıç [10], referred to the causes of fires that may occur on new construction sites and restoration works. He made suggestions for the prevention of these fires, and gave examples from the big construction site fires in Turkey.

In his thesis "Evaluation of Compliance with Occupational Health and Safety Rules in the Setup of Construction Site", Kabaroğlu [11] gave general information about fire safety measures on construction sites. He stated that after informing the relevant authorities, fire fighting should be done only by properly trained workers, using fire extinguishers in accordance with the class of fire.

In 2007, information on "What You Need to Know About Fire, Fire Classes, Fire Prevention, Fire Safety Instruction" is given in Chapter 15 of the book entitled "Construction Site Techniques and Occupational Safety at Work" written by Birecikli [12].

In her article entitled "The Place of Fire-Safe Design in Architecture Education" in 2016 [13], Korkmaz examined the educational situation of architects with regard to fire safety. Within the scope of the research, the curricula of the architecture departments in 90 universities in Turkey were examined, and a questionnaire study was conducted with the academic concerned. The results were evaluated and the author offered a number of suggestions.

2.INTERNATIONAL RESEARCH

In their study in 1999, Gambatz and Hinze [14] stated that construction site safety could be increased by design proposals at the project stage. In this research 10.4% of the 395 design proposals from different sources that were examined, mention the existence of fire hazards on construction sites.

Lynch [15] presented detailed fire safety protocols for heat and bituminous roof and insulation coatings, heat insulation, cutting and gluing used in fireworks, flame or spark cutting, paint removal by using heat, and welding, defined by hot works.

In their study conducted in 2004,Tam, Zeng and Deng [16] identified the weak elements of construction site safety management in the Republic of China. It was stated that accidents involving high-falls were the most common while accidents caused by fire and explosion did not constitute a significant risk.

In chapter 15 of the book Hudges and Ferret [17] explained in detail the fire risks that may occur on construction sites, what to do in order to prevent such fires, and fire fighting activities.

Li and Wang [18] stated that thermal insulation materials used in buildings are an important factor in the spread of many fires

In Liu, Wang, Sun and Sun’s [19] established an index system for the evaluation of fire safety by using the criteria of the publication, Technical Specification for Fire Safety in Construction Sites in the Republic of China. The security assessment index system for construction site fire risk is evaluated using fuzzy mathematical methods and the analytical hierarchy process (AHP).

The "Standards for the Protection of Construction, Modification and Demolition Works"[20] issued by the National Fire Protection Association (NFPA) and published in USA in 1968, was last revised in 2013.These Standards are about the prevention of fires onconstruction sites, and consist of the provisions for fire safety, and the rules that must be observed with regard to fighting fires.

In his study of the fires leading up to massive disasters in the United States in 2014, Badger [21] reported that the total cost of the damage in seven major construction site fires was $187 million. In the study, he also explained the origin of the fires and the fire detection and extinguishing systems used.

Roman [22] recently addressed the frequency of construction site fires in the US and the extent of the financial damage. As a result of the large construction site fires that occurred in 2014,the NFPA 241 regulations were examined. However, it was not deemed necessary to publish a revision. Roman noted that the issue was caused by a failure to apply the regulations with sufficient care.

In their studies in 2014 [23] and 2015 [24], Strömgren and Jönsson assessed the state of fire safety engineering in the European construction sector, and emphasized that a professional definition should be created.

Section 33 of the Oregon Fire Code issued by the International Code Council (ICC) [25] and revised in 2014, entitled "Fire Safety During Construction and Demolition", consists of fire safety measures that must be obeyed on construction sites.

In the study they have done to develop security measures in construction sites in Qatar, Senouc, Al-Abbadi and Eldin [26] undertook a literature review and identified 38 security risk factors compiled from the recommendations of occupational safety experts with regard to Qatari conditions. The responses from occupational safety experts were used to obtain the data. The study concluded that "The absence of adequate fire warning systems "is one of 18 unacceptable risk factors.

Gravity, Vaititcki and Shpakov's [27] study of the basic requirements for fire safety specified in the Russian specifications for tunnel constructions, indicated that the smoke evacuation systems, emergency exit calculations, fire classification in terms of building materials, and the point to be re-examined in terms of general fire resistance issues, have been addressed.

Ingason, Lönnermark, Frantzich and Kumm [28] summarized guidelines and solutions related to fire safety in underground facilities during the construction phase.

Garis, Maxim and Mark of the Canadian Wood Council (CWC) commented on construction site fire safety [29].

The HSE (Health and Safety Executive) in the UK [30] help clients, designers and those who carrying out construction work involving significant fire risks. This book is part of the HSE's series of health and safety guidelines for construction.

In the National Safety Council data sheet [31] in USA it is emphasized that the fire-loss potential during the construction phase is far greater than that which exists following completion.

In his study, Tsai[32] proposes an approach to assist construction managers with fire management. The aim of this study was to build an intelligent construction site fire management platform.

Gray and Arditi[33] examined the current fire prevention and protection methods used by the construction industry in USA. They analyzed the methods used, evaluated their success, and suggested alternatives to present practices. It was the goal of this article to present the potential dangers of during-construction fires in buildings.

In his study, Yong-sheng[34] analyzed the situation of the fast social economy and urbanization growth in terms of the consequent promotion of the construction industry, and also the increase in fire hazards. He discussed the methods of strengthening building construction site fire prevention in terms of rational distribution, building fire prevention, creating temporary fire facilities, and improving fire safety management, in order to prevent fire accidents effectively.

According to Johnson [35], fire is an important threat on any construction site, usually occurs as the result of a simple cause such as careless smoking, sloppy maintenance of electrical tools, unsafe portable heating, lack of an adequate fire watch, or faulty wiring Construction safety is a tough, often thankless work.

In his article, Chibbaro [36] explained that in May 2008, 14 employees were injured in a fire of a hotel under construction in California. Typically, building and fire codes, such as those promulgated by the National Fire Protection Association (NFPA) contain comprehensive lists of the provisions that should exist during construction.

In his article dealing with fire safety in buildings under construction Koffel[37] discusses the most common reasons of fires in construction and demolition. About 39.5% of fire incidents in buildings under construction are due to incendiary devices or suspicious causes, 20.8% are due to open flame, embers and torches, and 9.7% are due to heating equipment. Open flame is the most common cause of fire in

buildings under demolition, followed by incendiary devices or suspicious circumstances. Through the installation of fire protection systems, these common causes of fires can be prevented.

Sadler [38]points out that arson is now the leading cause of construction fires, and is the most difficult to combat. Defensive measures can be both active and passive. Active measures include guards, alarm systems, fences, and locks. Passive defense measures include good housekeeping and planning material delivery and staging, so that an arsonist is deprived of a fuel supply. Smoking is difficult to control on a construction site, but "No Smoking" rules should be enforced when flammable materials are used, and in fuel storage and equipment service areas. When planning a building project, an owner should look at the contractor's safety program and record. The safety program should include fire safety.

In their study, Yang Jun and Yang [39]proposed a new type of scaffold construction to reduce the problem of fire risk.

Kanterman [40] discusses the aspects to consider regarding fire and general safety during construction on an industrial site. He considers that safety orientation of all contract personnel, the general safety guidelines, hazardous work and permit systems, the handling of flammables and combustibles, the removal of all scrap and trash on a daily basis, the provision of dumpsters by contractors, fire prevention and protection and preplanning the construction site.

There was a news article published in the USA entitled "Fire Prevention & Safety for Buildings Under Construction" [41] which noted that, at the time of writing in 2017, there had already been 10 newsworthy events related to construction site fires.

An article entitled "Fires in Buildings Under Construction and Demolition"[42] discusses the factors to consider to ensure firefighters' safety on the ground when fighting fires in buildings under construction and demolition in the U.S. The factors noted include scaffolding fires, burning embers, construction-site hoist collapse, asbestos removal and fire protection systems.

In her study, Puybaraud [43] aimed to identify and propose a managerial model to foreclose and control fires during construction. The models name is Fire Safety Management Model (FSMM) which was developed to meet the requirements for fire prevention.

In the article by Verzoni [44], it was explained that buildings under construction have a tendency to burn. A recent NFPA report, "Fires in Structures Under Construction, Undergoing Major Renovation, or Being Demolished," in US found that from 2010 to 2014, there was an annual average of 8,440 fires in buildings under construction or being renovated or demolished. That's nearly two dozen such fires every day. The blazes also resulted in an annual average of 13 civilian deaths, more than 100 civilian injuries, and over $300 million in direct property damage. The report contains no information on the building materials involved in these fires, but presumably it was a diverse mix of materials typically used in building construction.

Tracy [45] presents the techniques used by fire fighters in the United States to conduct fire fighting operations in high-rise buildings that are under construction. This includes dealing with combustible materials prevalent on the building site, the basis of fire operation techniques, important things that should be determined by fire fighters upon arrival at the fire site and hazards that fire fighters should be aware of at the construction site.

In the 7th edition of the guidance document "Fire Prevention on Construction Sites" in UK there is an article entitled "New construction site code of practice launched" [46] which offers important information. It states that this guidance acts as a guide for planning adequate fire detection and prevention measures during construction projects. Moreover, revisions of the guidance include compliance with the requirements of the Construction Regulations 2007, guidance on managing fire safety at high fire risk sites, and requirements for the sitting and construction of smoking shelters.

In a news article from Russia it was stated that "Four people died in fire on a construction site in a Krasnodar suburb on Wednesday morning, the Krasnodar territorial department of the Russian Emergency Situations Ministry said. The fire broke out at the Victoria residential building under construction in the town of Lenin. An eyewitness reported the fire. The report was late, and two site

containers were ablaze when the firemen arrived. The fire spread over an area of 60 square meters. The flames were put out at 7:20 a.m. The firemen found four bodies inside the containers. They are being identified. The police are working at the scene of the fire. Eighteen firefighters with five machines put out the blaze. Causes of the fire are being investigated". [47].

"Construction fire protection", "Technical fire protection" and "Organizational fire protection" are three important part of the study undertaken by Neumann and Fehleisen. The main title of the study is "Safety on the construction sites of the Koralm Tunnel" [48].

Yang, He and Yang proposed a new type of scaffold construction scheme in their study entitled "Experimental Study on Feasibility of New Scaffold Construction Scheme in Preventing Fire Spread" [49].

Kumm and Bergqvist, [50] discussed the fire- and rescue services possibilities to perform a fire and rescue operation during the different phases of the construction.

Joon-Soo Kim and Byung-Soo Kim [51] studied the construction site fires and fire accident which was occurred at the construction areas.

A model scale study has been conducted in the project construction by Lönnermark, A., Hugosson,J. and Ingason, H. s to investigate fire safety in a tunnel during construction [52]

CONCLUSION

This paper has been an attempt at compiling and examining the available national and international scientific studies on the subject of "Construction site fire safety". It has been found that although there are many studies on occupational accidents and occupational safety in the construction industry, fire safety studies in this industry are inadequate.(Table 1)

It has been observed that fire safety in construction sites in Turkey is not adequately explained in the Occupational Health and Safety Regulation in Construction Works, and that these measures are mostly left to the risk analysis and check lists of occupational safety officers on the individual construction sites.

As a result of this study it has also been determined that there have'nt been done any scientific national study about fire safety in construction sites in Turkey (Table 1). There are some international study about fire safety in construction sites in but its not considered to be enough. (Table 1)

Table 1. The studies about fire safety on construction sites

Classification of Scientific Researches on the "Construction Site Fires"			
	Title	**Authors**	**Developed Model**
National Quantitative Research	-	-	-
International Quantitative Research	Analysis of fire-accident factors using big-data analysis method for construction areas (2017)	Joon-Soo Kim, Byung-Soo Kim.	
	Improving efficiency in emergency response for construction site fires: An exploratory Case Study. (2016)	Tsai MK	Knowledge-model-based mechanism for emergency response
	Experimental Study on Feasibility of New	Yang YH, Jun	-

	Scaffold Construction Scheme in Preventing Fire Spread (2013)	J, Yang JT	
	Experimental study on feasibility of new scaffold construction scheme in preventing fire spread (2013)	YangY, He J, Yang J.	-
	Study on safety assessment of fire hazard for the construction site (2012)	Liu H, Wang Y, Sun S, Sun B.	Analytical Hierarchy Process (AHP).
	Fire incidents during construction work of tunnels – Modelscale experiments (2010)	Lönnermark,A., Hugosson,J. and Ingason	-
	A Model of the Role of Management in Construction Fire Safety Failure Scenarios" (2001)	Puybaraud M.C.	Fire Safety Management Model (FSMM)
National Qualitative research	Şantiye Yangınları (2012)	Kılıç A.	-
International Qualitative research	Subway constructions fire safety regulatory requirements (2016)	Gravit,M., Vaititckii,A, Shpakova A.	-
	Construction Site Fire Safety " A Guide for Construction of Large Buildings" (2017)	Garis L, Maxim P, Mark K.	-
	Discussion on fire prevention of building construction site (2013)	Yong-shengYI.	-
	Safety on the construction sites of the Koralm Tunnel (2012)	Neumann DL, Fehleisen S	-
	Fire Safety In Construction (2010)	Health and Safety Executive	-
	Fire incidents during construction work of tunnels (2010)	Ingason H, Lönnermark A, Frantzich H,Kumm M	-
	Fire prevention and protection during construction .(1994)	Gray JA, Arditi D.	-
	Preventing construction fires. (2001)	Johnson L.F.	-
	How to prevent construction fires (1995)	Sadler JM.	-
	Construction site fire and general safety (1995)	Kanterman R. E.	

As this review has shown, more scientific studies with regard to construction site fire safety must be made undertaken by academic researchers. Such studies should be supported by private construction companies and by public sector organizations.

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