The Role of the Implementation of National Building Regulations in the Fire Safety Improvement of Industrial Structures

T. Askaripoor [1], GA. Shirali [2], R. Yarahmadi [3], E. Kazemi [*4]

1) Department of Occupational Hygiene Eng, Damghan Faculty of Health, Semnan University of Medical Sciences, Semnan, Iran
2) Occupational Health Eng Dept, Faculty of Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.
3) Iran Occupational Health Research Center and Occupational Health Eng Dept, Faculty of Health, Iran University of Medical Science, Tehran, Iran.
4) Department of Occupational Hygiene Eng, Damghan Faculty of Health, Semnan University of Medical Sciences, Semnan, Iran

**Author for Correspondence:* kazemie187@yahoo.com

Received: 24 Jan. 2016, Revised: 01 May 2016, Accepted:19 May 2016

ABSTRACT

In accordance with national building regulations, human safety and health should not be compromised in any way by the structures. Noncompliance with existing standards can increase the risk of fire in buildings. This study aimed to assess the impact of national building regulations on the reduction of the fire risk level in an industrial structure.

In this study, the fire risk level of the building and contents, occupants, and activities were calculated in a power plant control room using Fire Risk Assessment Method for Engineering (FRAME). In the following, by assessing the existing situation, the effect of the implementation of national building regulations was determined on the reduction of fire risk level.

The result showed that the fire risk level for occupants (20.64), building and content (1.02) that are above the acceptable level and corrective measures and design changes should be applied to reduce the risk level. Also, in case of application of the third chapter of Iranian National Building Regulations in power plant construction, the fire risk level will be reduced by 11.7% compared to the existing situation

This study showed that the implementation of national building standards and regulation can provide the occupants life safety by correctly predicting escape routes. Fire Risk Assessment Method for Engineering (FRAME) is a very effective tool for selecting the best control strategies for fire safety of industrial structures.

Key words: Fire, Fire Risk Assessment, National Building Regulations, Power Plant

INTRODUCTION

Fire safety is one of the most important issues in the process of designing and constructing buildings. Likewise, 75% of fire caused damage is predictable and preventable by implementing the safety rules and regulation [1-3].

The governments have played an important role in the formulation of fire protection regulations and monitor the implementation of these regulations. The national regulations will determine the minimum requirements for fire protection and prevention in the design and construction of buildings.

In our country, Chapter III of National Building Regulations derived from NFPA laws is a general guideline for the safety of buildings against fire, which is applied by setting the limits, the minimum dimensions of space, ventilation, and other general requirements designed to ensure safety, health, productivity, comfort, and economic efficiency and meeting the minimum needs of the occupants and users of buildings [4-5].

In general fire safety regulations must provide a level of safety that can reduce the occurrence and spread of fire and prevention of building destruction. It also must be allowed firefighters and rescue forces entering the buildings and the evacuation of residents [4 and 6].

Fire Risk Assessment Method for Engineering (FRAME) method was invented by Belgium Fire Protection Association in 1981 by completing the Grentener methods that used in assessing the financial risk of fire and insurance [7]. In this method unlike building codes methods that based on escape safely occupants is based on protecting the structures, contents and activities [8]. Also this method has been introduced as an effective means to evaluate new or existing buildings due to having such advantages as a high speed and accuracy and cost-effectiveness.

In the study conducted by NG (2003) in an airport terminal building, by using FRAME, showed that the risk of fire for occupants, more than the risk of damage to property and equipment. As well as, due to observing the principles of fire safety during the design and construction, the airport building has an acceptable level of risk [9].

Also, Charters' study (2013) revealed that system designers through taking passive protection measures at an early stage of design and enhancing redundancy and reliability are able to reduce the fire risk in large units by spending a minimal cost [10].

Power plants are considered as one of the most important infrastructures for developing countries is subject to risks and multiple events, including fire. To the authors' knowledge, no study to date in the country has investigated the status of national building regulations for fire prevention in thermal power plant building. This study was carried out using FRAME to determine, the effect of the implementation of national building regulations on the reduction of fire risk level.

MATERIALS AND METHODS

The study was done in a thermal power plant in the south - west of the Iran country. Given that the FRAME method used is necessarily applicable in a closed space, the control room was chosen as the place of implementation of this method after examining the various units of the plant.

FRAME guidelines have a high frequency of information and parameters to calculate the fire risk level in FRAME, with the aim of increasing speed and precision, a check list was built by authors on the basis of all the information mentioned in the method instruction. Response to each question in the Check List specifies a variable to calculate the fire risk level. Information necessary to calculate the risk level was collected using the mentioned checklist through observation, interviews with people and officials or with reference to the documents. In the study of the power plant building, the factors were taken into consideration such as the height of the unit of the earth's surface, the possibility of the influence of fire outside the unit, type of activity and the workers' character.

Also, due to the multiplicity and complexity and extended calculations used in FAME, EXCEL software package has been provided for the calculation of risk level. In addition, this computational package also has enhanced accuracy and reduced the possibility of errors in the calculations. It is to be mentioned, the FRAME method validity was compared to three other methods in the real case studies. The results of all three studies have confirmed the validity of FRAME. Also, influence factors that are used in FRAME are similar to the international regulation of fire [8].

In this study, fire risk assessment was done according to the latest version of the FRAME method that published in 2008 [8 and11]. According to the method, the parameters were calculated such as the potential risk level, acceptable risk level and risk protection level for each risk. Finally, fire risk levels were calculated separately for the building and the contents (R), occupants (R1), and activities (R2). Figure 1 shows the effective parameters for risk level calculations. The important aspect in FRAME that can estimate the normal expected losses to build and contents based on the calculated fire risk level (Table 1)

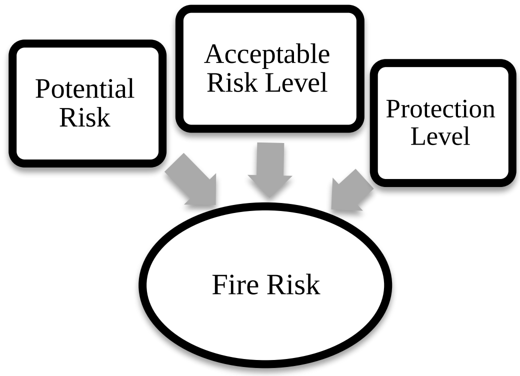

Fig. 1. The parameters affecting the calculation of fire risk levels in FRAME

Table 1: The expected normal losses for the building and the contents

Fire risk levels for the building and the content (R)	Percent of destruction for Building and content
Up to 1	10% or less
1.0 to 1.3	10 to 20%
1.3 to 1.5	20 to 30%
1.5 to 1.7	30 to 50%
1.7 to 1.9	50 to 80%
More than 1.9	80 to 100%

Also, by using table1 and on the basis of the expected damage to the building and contents can determine fire control and management measures in industrial buildings according to the following guide:

When calculated risk level is less than one: risk level is acceptable and use public methods such as the extinguisher and fire station is enough. It may be sometimes necessary to use additional measures to protect the occupants and activities.

If the calculated risk level is more than 1 and less than 1.6: the use of automatic fire detection systems, is essential for the warning, and rapid action of fire fighter team. Also, the provision of adequate water resources and adoption of additional measures are required to protect the occupants and activities.

If the calculated risk level is greater than 1.6 and less than 4.5, the use of automatic fire extinguishing system such as sprinklers and sufficient water supply is essential. Finally, if the calculated risk level is greater than 4.5, must be used all the above solutions to reduce the fire risk level [8-12-13].

RESULTS

In this research, fire risk levels for building and occupants were determined within an unacceptable level (Fig. 2). The details of the calculation to determine the fire risk level are showed in table 2. According to table 1 and calculated risk of fire in this study, can be found in the event of a fire, 20 - 10 percent of the building and the contents of the control room, will be destroyed. Also, based on calculated fire risk level (1.02) should be installed automatic fire detection systems for the warning and rapid action of fire fighter team. Installing this equipment can be minimizing the potential damage in the event of a fire.

In the FRAME method, various factors are involved in determining the fire risk level. With the modification of each of the following sub factor, relevant factor and thus fire risk level will change. In this study fire risk level for occupants and building obtained more than acceptable level and preventive measures and design changes should be applied to reduce the risk level. So, therefore, the effects of the 3 sub factors include constant fire load, number of floors, and changes in the dimensions and area of the control room were assessed in the software (Table 3).

The impact of the implementation of these measures in fire risk level reduction is about 40%, which are very significant.

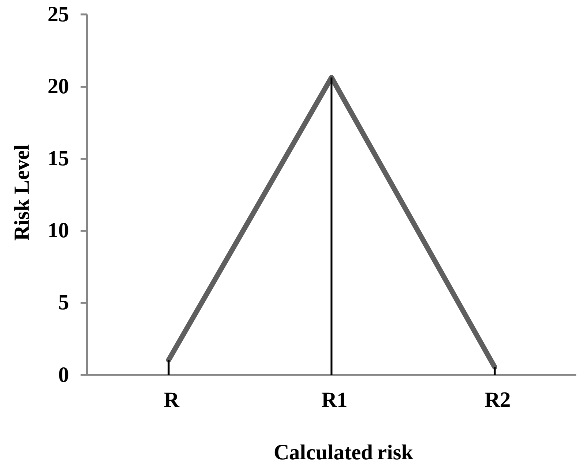

Fig 2. Fire risk level calculated for building, (R), occupants (R1), and activities (R2)

Table 2: The results of the details of the calculation to determine the fire risk level

Calculated sub factors	Value	Fire risk levels	Value
Potential Risk for building (P)	4.33	Building (R)	1.02
Acceptable Risk Level for building (A	0.99		
Protection Level for Building (D)	4.26		
Potential Risk for occupants(P1)	4.01	Occupants (R1)	20.64
Acceptable Risk Level for occupants (A1)	0.073		
Protection Level for occupants (D1)	2.64		
Potential Risk for activities(P2)	0.63	Activities (R2)	0.56
Acceptable Risk Level for (A2) activities	0.3		
Protection Level for activities(D2)	3.88		

Table 3: Results of the effects of corrective measures on the fire risk level of occupants

Terms of calculated risk level	**Symbol**	**Risk level**
The calculated risk level in the existing situation	R_{1-1}	20.64
The calculated risk level, assuming a constant fire load reduction through the establishment of a non-burning or maximum 10% burning building	R_{1-2}	18.14
The calculated risk level, assuming the control room establishment on the ground floor instead of the 4th floor to increase accessibility and facilitate an emergency exit	R_{1-3}	13.40
The calculated risk level, assuming the control room establishment with an area twice the size of the current area	R_{1-4}	12.54

DISCUSSION

The study showed that the fire risk level for occupants (20.64), building and content (1.02) that is above the acceptable level in the frame method. Due to the passage of a long time since the power plant construction, old design, a lack of foresight fire extinguisher equipment at the time of the construction, lack of proper maintenance and merge facilities, not out of expectation.

The results of the present study showed that the expected destroy in the control room would be 10-20% in the event of a fire. As well as, the control room on the fourth floor of a plant and has two outputs that path towards being open to the main site

and high risk areas. Also, apart from the main staircase access there was no exit.
It is important to note that in case of application the third chapter of Iranian National Building Regulations in power plant construction, the fire risk level will be decreased by 11.7% compared to the existing situation. As well as in the case of building a control room in the ground floor, due to the increased access to firefighting, facilitate rescue operations and evacuation of residents, the fire risk level will reach to 13.40 (a 35.1% decrease compared to the existing situation. Also, if the minimum acceptable space is observed for activities, sufficient space is provided based on the number of population and kind of equipment, the risk level significantly could be reduced.
In Ibrahim's studied, passive protection methods have the most influence in controlling the outbreak of fire. Similarly, in the present study, the passive protection methods, such as building the control room on the ground floor instead of the 4th floor, predicting space activities according to the development of the power plant could lead to a significant reduction in the fire risk level [14]. Yarahmadi *et al.* determined that the fire risk level in the studied hospital is high and it was seen that the building rules had not provided enough safety in the hospital building and there were a need to revise the regulation [5]. Additionally, Mehdinia *et al.* showed that fire risk level in studied hospital for occupants was higher than the acceptable level and use the active protection methods, such as an appropriate rescue and evacuation plan would lead to a significant reduction in the fire risk level [15].
It is important to note that adds to this day in Iran no research has been carried out to examine the impact of the application of the fire prevention laws and regulations in industrial buildings, such as power plant. Most these studies have been done in health and medical installation so could not compare present study results with other studied. This issue is a limitation of the present study
Fire safety is one of the major issues in the process of designing and building industrial structures. Building fire safety has two main goals: life safety and financial safety. Formulation and implementation of the fire protection standards and regulations in buildings reduced the life and financial losses. The present study showed that the implementation of national standards and regulation can provide the occupants life safety by correctly predicting escape routes and facilitate the withdrawal of residents of the buildings. Also, financial safety obtained with resisting building components in front of the fire
In the Marberg study, the use of performance-based rules and regulations has been introduced as appropriate way to achieve its goals and it has been suggested that designs based on engineering methods as much more affordable of existing laws [16]. Also, in the Jonsson study has been emphasized by the use of risk assessment methods for selecting certain engineering methods of fire safety [17].
The present study showed that in terms of legal and ethical; determine the effect of the existing laws and regulations on the fire risk level has a high importance. At the end, it can be said that the Fire Risk Assessment Method for Engineering (FRAME) is a very effective tool for selecting the best control strategies for fire safety of industrial structures. Also, it is recommended to use other methods in future studies, to determine the shortcomings and improve the level of national building regulations.

CONCLUSION

Fire safety is an important issue in the process of building design and construction. This study showed that the implementation of national standards and regulation can provide the occupants life safety by correctly predicting escape routes. Also, FRAME is a very effective tool for selecting the best control strategies in fire safety.

ETHICAL ISSUES

Ethical issues such as plagiarism have been observed by the authors.

COMPETING INTEREST

The authors have declared that there are no conflicts of interest.

AUTHORS CONTRIBUTION

All authors equally participated in drafting, revising and approving of the manuscript.

FUNDING/ SUPPORTING

Authors of the manuscript have not received any funding for present study.

REFERENCES

[1] Brauer RL. Safety and health for engineers. Second ed: John Wiley & Sons; 2006.
[2] WHO. A WHO plan for burn prevention and care. Geneva, Switzerland: World Health Organization, 2008.
[3] Ramachandran G. The Economics of Fire Protection.1 ed. London: E & FN Spon; 1998. 1-10.
[4] Department of Housing and Urban Development, The third topic of national building regulations 2009.
[5] Yarahmadi R, Gholizade A, Gafari M, Koohpayee A, Mahdinia M. Evaluation of the

national regulations, building approach to fire safety in inpatient parts of a hospital. Iran Occupational Health Journal 2008; 6 (1): 28-36.

[6] Jafari MJ, Haji Hoseini AR, Halvani GH, Mehrabi Y, MI Ghasemi. Prediction and Analysis of Human Errors in Operators of Control Rooms at 400 KV Posts and the Effectiveness of the Proposed Measures. Iran Occupational Health. 2012; 9 (7): 60-71.

[7] Setare H, Koohpayee A, Nikpey A. Development of risk analysis in fire risk assessment, Conference: First National Conference on Safety in Ports, Tehran. 2005.

[8] Smet E. FRAME 2008, Theoretical Basis and Technical Reference Guide, 2008, Accessed in 2013.

[9] Ng M. Fire Risk Analysis of the Airport Terminals. International Journal on Engineering Performance-Based Fire Codes. 2003; 5 (4): 103-07.

[10] Charter S. The application of fire risk assessments in building design and management. Fire Protection Engineering 2013. Available from: http://www.sfpe.org/?page=2013_Q3_2

[11] Shirali G, Yarahmadi R, Kazemi E. Determining the Risk of Fire by Engineering Approach and Provide Practical Protection Strategies (Case Study - A Thermal Power Plant). Iran Occupational Health Journal. 2015; 12 (5) :80-89

[12] Sakenaite J. A Comparision of Methods Used For Fire Safety Evaluation. Civil and Transport Engineering. 2010; 2(6): 36-42.

[13] Sakenaite J, Egidijus R. Fire Risk index and Fire Risk analysis: A Comparision of PROS and CONS, Conference: 10th international Conference on modern building, lithuania. 2010.

[14] Ibrahim M, Mohddin A, Abdulhamid K, Yunu R, Yahya M. Fire risk assessment of heritage building-perspectives of regulatory authority. Procedia engineering. 2011; 20: 325-28.

[15] Mahdinia M, Yarahmadi R, Gafari MG, Koohpayee A, Kazayee M. Fire Risk assessment and a plan of rescue, evacuation and reduce the amount of hospital care. Qom university of medical sciences. journal 2011; 5(3): 71-78.

[16] Marberg A, frantzich H, Jonsson R, Lundin J, Rantat T. Practical Design and Performance Based Regulations.Fire Science &Technology. 1998;18 (1): 33-42.

[17] Jonsson R, Lundin J. Fire Risk Design Based on Risk Assessment. Fire safety & Technology. 2000; 20(1):13-25.