Acta Technica *62* (2017), No. 7A, 1383–1394

Application and analysis of crowded crowd evacuation model in multi-function gymnasium under fire conditions

Haiyan Wang[1]

Abstract. Targeted at personnel evacuation in multi-functional gymnasium under fire conditions, the relevant parameters are calibrated and the correlation between the parameters of personnel evacuation model of gymnasium is clarified by using key node method, travel time method and other research calculation methods, combined with the derivation and application analysis of personnel evacuation model of the buildings. The derivation formula of evacuation model for related people is integrated through the calculation and discussion on crowded evacuation under the simulated fire conditions in the gymnasium shown in the project case, and the further analysis is carried out by combining with actual case. The research results can not only provide reference for the actual building design and reconstruction of the multi-functional gymnasium, but also guide the evacuation of the managers in gymnasium, so as to provide computing equipment for avoiding the accident arising from space-time meeting due to various risk factors.

Key words. Fire, Gymnasium, Evacuation, Model

1. Introduction

The construction of multi-functional gymnasium has entered a period of high development with the rapid development of China's economy, and these gymnasiums are not only the main bases for holding sports events, but also public places for large gatherings and cultural activities, showing the characteristics of the coexistence of hidden security risks such as highly intensive personnel, large probability of fire risk and difficult safe evacuation, etc. Simultaneously, it shows a trend of complication, integration and diversification in current sports building with the development of

[1]Department of Physical Education, Heilongjiang Bayi Agricultural University; Daqing 163319, China

architecture science and the multi-functional needs of the gymnasium [1]. In recent years, all countries in the world have enhanced their investment and research on emergency evacuation management. Many scholars at home and abroad rely mainly on computer simulation and mathematical analysis to carry out related research. Although all kinds of research results are widespread, the research of alarm, response and action under the condition of primary fire disaster and secondary disaster combined with detention personal evacuation and overall consideration is not widely in China. This paper compares and analyzes evacuation difference of different fire spots under fire conditions and normal conditions in the case of virtual engineering by virtue of mathematical analysis methods, so as to provide practical proposal for engineering reconstruction, thus providing evaluation basis and reference for design, management and reconstruction of the multi-functional gymnasium.

2. Specific factors and parameters involved in the research

2.1. Setting of specific factors and parameters involved in crowded evacuation

The specific factors involved in research on personnel evacuation for multi-functional gymnasium are diversified, which not only includes the related factors of the gymnasium design, such as length and effective width of evacuation passageway and potentially detained area, but also includes factors related to the specific population of the evacuation such as number of people, movement speed and the possibility of a panic riots, etc.

With respect to crowded evacuation, the domestic and foreign scholars have given specific formulas and empirical constants through calculation and deduction without considering the sudden change of the environment and the population.

(1) Effective boundary dimensions of evacuation passageway

The reduction value of effective breadth is given in the Handbook of Fire Protection Engineering published by SFPE, which points out that the corresponding boundary dimensions shall be subtracted in the actual evacuation measurement and calculation to obtain effective width of passageway, that is, the width of the staircase is 15cm, the width of the horizontal channel is 20cm, and the width of the gate is 15cm.

(2) Relationship between population walking speed and density

Crowd density is usually expressed by the number of people per unit area:

$$\text{Crowd density } (\rho) = \text{overall number of people/ occupied area (person/ m2)}\,. \quad (1)$$

The function relationship [2] between density and speed can be expressed as follows:

$$u = u_0 \cdot \rho^{-0.8}\,. \quad (2)$$

In the above formula, ρ represents the crowd density and u_0 means a constant, namely 1.34m/s. According to the calculation, the experts in China point out that, the movement speed of population will decline as the crowd density rises, of which the corresponding relationship is as follows, namely, 1.5 persons/m2-1.0m/s, 2.0 persons/m2-0.7m/s, 3.0 persons/m2-0.5m/s, 4.0 persons/m2-0.35m/s, and 5.38 persons/m2-0.0m/s.

(3) Forecasting speed of personnel evacuation in different parts of the buildings

A person's walking speed in an emergency is related to many factors. Based on practical research, without considering other factors, the domestic scholars believe that, the movement speed of the people under normal condition is 1m/s at horizontal channel, 0.50m/s at seat area, 0.45m/s when climbing the stairs and 0.60m/s if walking down the stairs. However, in consideration of major difference under the circumstances of crowd evacuation in the gymnasium and orderly retreat under normal condition, the widely accepted crowd evacuation speed setting is a constant, namely 1.34m/s, at the present stage in China.

(4) Crowd flow rate and crowd flow

Crowd flow rate (person/m/s) is the measure of availability factor for channel, and its specific calculation formula can be expressed as:

$$\text{Crowd-flow rate} = \text{number of persons passing through}/\ (\text{passing through time} \times \text{channel width})\ (\text{person/m/s}) \tag{3}$$

According to the relation model of crowd flow rate and crowd density derived by Liu Yu et al, the calculation formula of f is as follows:

$$f = 2.27\rho^{0.5} - 0.374\rho^{1.5}\,. \tag{4}$$

The crowd flow is closely related to the crowd-flow rate, which can be expressed as follows:

$$F = v\rho W\,. \tag{5}$$

F means the crowd flow through channel exit in specific time interval (person/s); f represents the crowd flow rate (person/m/s), v refers to the movement speed of crowd (m/s), ρ means the crowd density (person/m2) and W refers to the exit width (m).

Constant setting of crowd flow: setting a single stream of people according to the Chinese Design Code for Sports Buildings and relevant researches, taking $F = 40\sim42$ person/min is more scientific in view of exit staircase and other factors. As the crowd evacuation is only able to take positive integers, it is designed to evacuate 1 person every stream of people per 1.5s at exit, and the time interval in the formula is $t = 1.5$s. The evacuation time can be done in the same manner.

2.2. Factors affecting evacuation in fire

(1) Influence of primary fire disaster on evacuation

The research results in regard to inside fire over the years at home and abroad show that, smoke toxicity, asphyxia caused by hypoxia and radiation heat are the main causes of casualties in the fire. Toxic gases emitted from fire can directly cause harm to people, and reduce oxygen content in air with non-toxic flue gas, resulting in the risk for suffocation of crowd that is not evacuated in time in buildings. At the same time, the radiant heat of the flame will increase the temperature in the building rapidly due to the closure of the buildings and quickly reach to fatal level. Therefore, the primary fire disaster of the gymnasium will cause a lot of casualties in a very short period of time if the evacuation is stagnant caused by too long evacuation time or the appearance of anthill in the evacuation process.

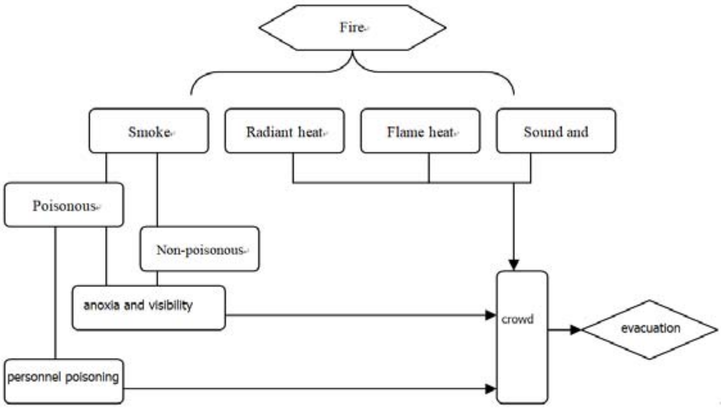

Fig. 1. Influence of primary fire disaster on evacuation

(2) Influence of secondary fire disaster on evacuation

By analyzing a large number of cases, we can find that, the grave consequences of all accidents in the gymnasium are caused by a variety of accident cause. The specific process can be summarized by the accident causal chain theory, that is, the primary disaster causes the secondary disaster, such as personnel detention and crowd caused by a variety of reasons in the process of evacuation, producing "arching phenomenon". If an accident such as personnel fall down occurs during the collapse of the "arch", it will inevitably cause a stampede. The existing cases in the world show that, stampede accident has become the main cause of the casualties during the emergency evacuation of the dense crowd.

3. Derivation of quantitative model for safety evacuation in gymnasiums

3.1. Setting for time nodes of safety evacuation in gymnasiums under fire conditions

(1) Definition of time node for fire development

According to the fire development stage proposed by the Chinese domestic scholars, the fire of the building is classified into beginning stage, development phase, violent stage, attenuation stage and extinguishing stage in general. It is pointed out that generally, the area of the fire is not large within 10-15 minutes in the beginning stage when solid matter is burned, and the fire spread slowly to the surrounding area because of slow flow rate of smoke and gas and low radiant heat, so the combustion has not broken through the housing shell in general. This stage is the best time to warn of fire.

For the gymnasium, there are three kinds of evacuation time node classified by Chinese domestic scholars, of which one is classification of low fire hazard. The structure includes open platform and stand with completely protected food and beverage export made of incombustible material. The emergency evacuation time for all viewers to reach the safe area in the event of a fire is not more than 8 minutes. Second is classification of normal fire hazard. This structure has a low risk of fire spread and relatively controllable, and has the necessary effective fire extinguishing system or control system. The emergency evacuation time for all viewers to reach the safe area in the event of a fire is not more than 6 minutes. Third is classification of high fire hazard. This structure is mainly a closed gymnasium with a large number of flammable objects, and the layout of the space may promote the spread of fire, heat propagation and gas expansion. The emergency evacuation time for all viewers to reach the safe area in the event of a fire is not more than 2.5 minutes [3].

Of course, the structure of different gymnasiums is also quite different in itself in the actual case analysis, and at the same time, even if there is a fire in the same gymnasium, there will be some difference in the time period due to different fire points, which requires us to make a judgment based on the actual situation.

(2) Available evacuation time definition model

When a fire occurs in the gymnasiums, the crowd evacuation in the gymnasium depends on two safe evacuation time nodes, of which one is the time that needs to be consumed for the last person to safely evacuate to a safe area, expressed by T_{RSET} generally, but it must be pointed out that, T_{RSET} is not just the evacuation time of the personnel in the gymnasium in the practical application process, but also the time of fire alarming (T_A), response time (T_R), and evacuation time (T_M), in which, T_{RSET} shall be the sum of T_A, T_R and T_M; and another one is the time to guide the personnel in the gymnasium to evacuate after a fire is found until the fire development poses a personal threat to the safety of detained personnel in the gymnasium, expressed by T_{ASET}, in general. Only if $T_{RSET} < T_{ASET}$, it is possible to evacuate the personnel in the gymnasium safely.

The determination method for time of fire alarming (T_A) is mainly based on early-warning time of existing fire electronic alarm. The existing research data show that, under the condition of rapid fire and in the case that the bimetallic fixed temperature fire detector is 2.5m away from the fire source, the early-warning time is about 112S [4].

The actual early-warning time varies with the fire and the distance from the fire source.

From the beginning to the end of safe evacuation, the travel time method can be used to calculate the time required for evacuation without considering loss of time caused by various factors due to a fire. However, the numerical value calculated by the travel time method is not the one represented by T_M. Scholars at home and abroad generally believe that, this numerical value shall be multiplied by a safety factor because of the influence such as personal factors and recessive structural factors for gymnasium design, to try to close this numerical value as much as possible to the actual required time, with taking value interval from 1.5 to 2.

Travel time method:

$$T = N_a\,/fB_{\min} + l_{\max}/v\,. \tag{6}$$

In above formula, T represents the time required for the evacuation, N_a refers to the total number of the people waiting to evacuate in the gymnasium, f represents the crowd flow rate (person/m/s) in the evacuation passageway, $B_{\min}$ means the minimum effective width of the evacuation passageway during the evacuation process, $l_{\max}$ refers to the maximum walking distance of evacuate parts contained in the evacuation area to the safe site and v represents the theoretical moving speed of the crowd.

However, what needs to be pointed out in this paper is that, the "arching phenomenon" of individual nodes on the evacuation route in the evacuation process inevitably leads to the inevitable interference from the evacuation action to a certain extent when fire and other disasters occur. Therefore, we must consider the problem of personnel detention in the actual case analysis, and properly extent the time to evacuate the evacuation passageway where there may be detained personnel within a certain scope.

Calculation model of detained personnel in evacuation passageway:

$$\begin{aligned} N &= \sum_{i=0}^{k}\int_0^t F_i(t)dt - \int_{t_0}^{t} F(t)dt = N(t-1) + N_d = N(t-1) + N_i - N_e \\ &= N(t-1) + 1.5akF - 1.5Wf\,. \end{aligned} \tag{7}$$

This model is derived by Chinese domestic scholars according to the formula for building evacuation time derived by Togawa and cluster flow model proposed by other scholars under the comprehensive consideration of the characteristics of the evacuation passageway inside the gymnasium in China, suitable for design model of evacuation passageway with multiple branch entrance in single exit, where, $F_{i(t)}$ represents the crowd flow of the ith branch entrance of the evacuation passageway at moment of t, $F_{(t)}$ refers to the crowd flow of evacuation passageway exit at moment of t, a means the number of stream of people at stand evacuation channel, k represents the number of branch entrance of the passageway, t_0 refers to the crowd retention time from the beginning of the evacuation to the exit section and t_1 means the rush hour of stand exit when the crowd density of stand exit reaches to 5.38 person/m2.

4. Analysis on application example of quantitative model for personnel safety evacuation in multi-functional gymnasium under fire conditions

With the development of China's economy in recent years, the steel structure and frame type design are generally adopted in the newly constructed multi-functional gymnasium, and the scale of the building generally reaches the Grade-I and Grade-II of fire resistance rating. To meet the needs of watching games, the stands distributed in both sides are adopted in the design. Therefore, the selection of engineering cases mainly refers to the above two standards when analyzing the application of personnel safety evacuation model for multi-functional gymnasium under fire condition.

4.1. Actual situation of engineering cases

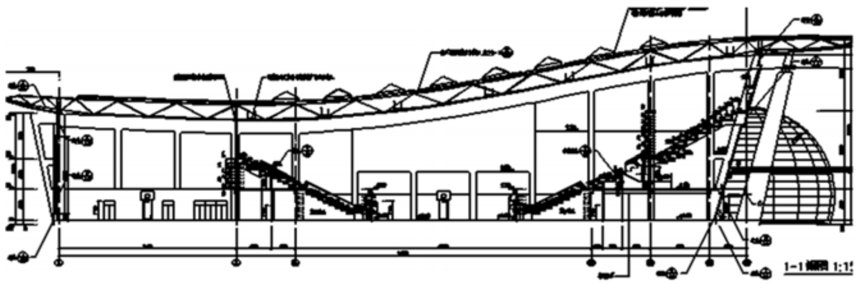

Fig. 2. Exterior view of gymnasium

The engineering case for the research is the new multi-functional application properties gymnasium built in a school, including main and associate hall for activities. The main hall is a two storey structure, with a total of about 1500 seats in the first mobile stand and about 2000 seats in the second stand. The associate hall is a single layer structure. The gymnasium is connected to the outside world with 5 exits, and the first floor is connected to the 8 exits of the corridor, and the width of the staircase between the first and the second floor is 2.30m-2.50m. Equipped with the fire resistance rating of Grade-I, the gymnasium is mainly undertaken for commercial performances, sports competitions, group gatherings and daily physical education tasks. Its daily maintenance is in good condition (exterior view of gymnasium, see Figure 2).

4.2. Simulation calculation of evacuation of the gymnasium under fire conditions

There are 8 exits with width of 1.5m inside the first floor of this gymnasium to 5 main evacuation passageways, and there is no obvious evacuation bottleneck in the design (see Fig.3), so the key node method is considered to calculate the evacuation time of the seat at first floor of the gymnasium in this research, which can be expressed as follows:

$$T_M = \frac{N}{AB}\,. \tag{8}$$

In the above formula, N represents the audience number waiting to evacuate of the mobile stand at first floor of this gymnasium, A refers to the crowd flow per stream of people per unit time and B means the number of stream of people. The numerical value of crowd flow depends on stability and efficiency of crowd flow

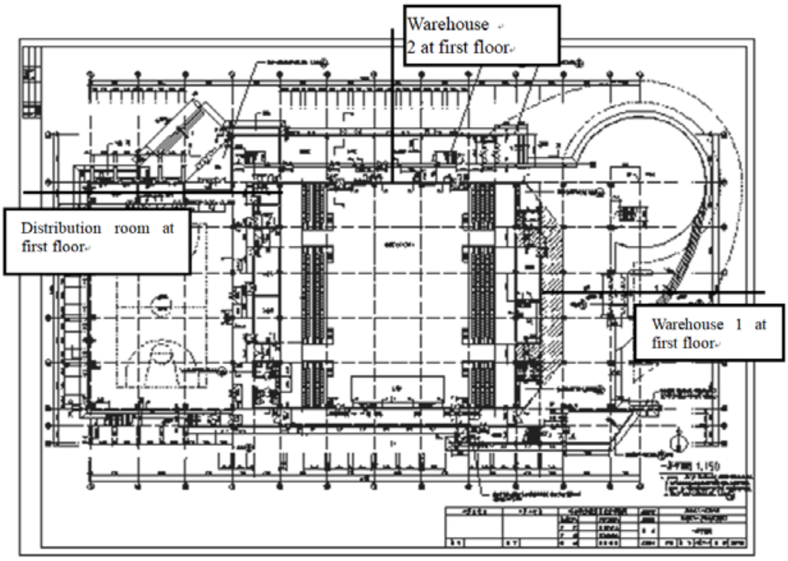

Fig. 3. Aerial view of first floor of gymnasium

during the evacuation, and the number of stream of people depends on the width of the evacuation passageway.

On the premise of no crowded stampede, the safety factor can be set as 1.5 as the case may be. The evacuation time of a mobile stand at the first floor of the gymnasium is $T_M = 1500/\ (16*40/60)*1.5 \approx 210\text{S}$, plus time of fire alarming T_A(120s) and response time T_R(30s), so that the overall evacuation time (T_{REST}) can be controlled within 360s.

Fire prone locations in multi-functional gymnasiums are mainly concentrated in warehouses and distribution rooms, etc. There are two warehouses in the entrance hall at the first floor and the north of the case venue and a distribution room is established in the northeast at the first floor. Based on this, the evacuation time can be recalculated after the virtualization of origin of fire. The virtual results show that, at least 2 internal field evacuation passageway doors are affected by fire at any flammable place. The result of the recalculation under fire conditions is $T_M = 1500/\ (12*40/60)*1.5 \approx 281\text{s}$, plus time of fire alarming (T_A) and response time (T_R), so that the overall evacuation time (T_{REST}) can be controlled within 430s.

As the building scale of such gymnasium has reached to Grade-I fire resistance rating, so the safe evacuation time at the first floor shall be higher than the classification time limit of the high fire hazards of 2.5 minutes (150s) as mentioned above, in the absence of power off or under normal working conditions of emergency lighting system. It shall be close to the classification time limit of normal fire hazards, i.e. about 6 minutes (360s). We can find out that, by comparing the calculation results under the virtualization of fire with the standard time for safe evacuation, the evacuation time has exceeded the safe time if a fire occurs at the first floor. If a suggestion is made from the actual operation, only to minimize time of fire alarming

(T_A) and response time (T_R) is an effective way to solve the possible problems.

There are 4 exits with width of 2.5m-2.9m in the fixed stand at the second floor of the gymnasium to the evacuation passageway at the second floor, and the fireproof door is also provided. Therefore, the actual width of the exit is between 2.3m and 2.7m, and the specific architectural structure design is shown in Fig.4.

There is 1 passage in the second floor of the gymnasium directly connected to the outside world (passage 1), and the rest of four passages must be able to connect to external safe area via the first floor. Therefore, it is more appropriate to use the travel time method in calculating the evacuation time. Under sudden conditions of non-emergency, first access to the corridor via 4 exits at stand at the second floor, then access to the evacuation passageway via the corridor respectively to arrive at the safe area in the end. If the safety factor of the evacuation time is 1.5, the calculated evacuation time (including time of fire alarming (T_A) and response time (T_R) of each stand at the second floor is mainly between 280s and 550s under the full consideration of the complex structure of the second floor for the gymnasium. The evacuation time of stand d, e and f is higher than 520s, showing that the evacuation time of some of the stands has exceeded the maximum evacuation time limit of the low fire hazard, i.e. 480s. This result is mainly caused by the design defects of the exit of stand d, e and f. Due to the use of stepwise structure in terms of the design and construction of the exits, the 90° corner (see Fig.5) as well as rotating staircase structure of the evacuation passageway, the detained population is formed in the entrance of these exits. In addition, the number of seats in the stands is relatively large, resulting in that the evacuation time of the stand exceeds the safe standard under sudden conditions of non-emergency, finally.

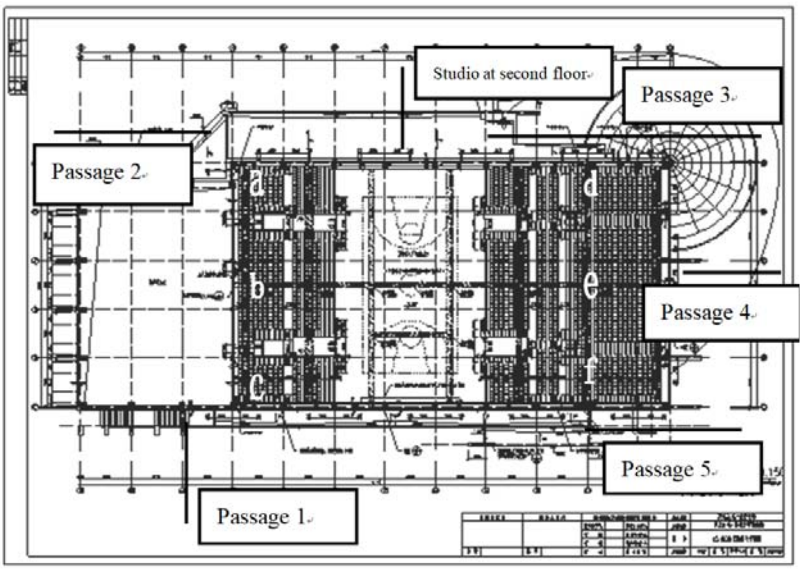

Fig. 4. Aerial view of second floor of the gymnasium

In theory, the studio at the second floor of the gymnasium is prone to be on fire.

Fig. 5. Schematic diagram for design defects of exit of stand d, e and f

Considering that there are always workers working in this place during the full use of the gymnasium and this place is also located in a relatively safe position in the design of the gymnasium, the discussion will no longer be discussed in subsequent analog calculations.

As only passage 1 of the stand at second floor of the gymnasium is directly connected to external safe area, a major influence will be exerted on the evacuation of the stand at second floor of the gymnasium if there is a fire in the warehouse and distribution room at the first floor of the gymnasium. Considering that the warehouse 2 at the first floor of the gymnasium is located in the middle part of the corridor equipped with fireproof doors at both sides, this easy fire place does not affect the evacuation of the stand at second floor under the condition of virtual fire. However, if there is a fire in the distribution room at the first floor of the gymnasium, the people at the stand a, b and c only can be evacuated through the stand exit between stand b and c. The width of this exit is 220 and the effective width of actual evacuation is 205, which can accommodate 4 streams of people to evacuate. Because of the close distance to the safe exit, the evacuation time is calculated for $T_M = 500/$ (4*40/60)*1.5≈187s by key node method, plus time of fire alarming (T_A) and response time (T_R), so that the overall evacuation time can be controlled within 340s. Because the crowd is away from the fire point gradually in the evacuation process, therefore, the crowd's behavior will tend to the rational condition, and the possibility of stampede accident incurred thereby is relatively low. At the same time, as the initial position of the people at stand d, e and f is far away from the fire point, therefore, it basically obeys the level of smooth evacuation, and if people are able to evacuate rationally, they can be evacuated in about 530 seconds. It is important to pay attention to the rational guidance of the people at these three stands so as to avoid the stampede accident.

If a fire occurs in the warehouse 1 at the first floor, the main evacuation passageway 4 (located in front door of the gymnasium) will be closed. Due to the influence of various factors (smoke toxicity, anoxia induced asphyxia and radiant heat) from primary fire disasters, the people in the stand d, e and f above the fire will be in a state of panic in a short period of time and rush to the two exits of the stand driven by the desire for survival. Based on the calculation model of detained number of evacuation passageway, we can find that, the detained people in these exits will rise sharply in a short period of time, and the number of evacuees at around 1.5s is 4 at the stand exit, while the number of people who enter into the area waiting to evacuate in the same period is 6. When the number of people in the 6m2 area waiting to evacuate reaches the maximum of crowd density, namely 5.38, there are 32 persons to be accommodated, that is, it takes 24 seconds from the evacuation to the saturation. It is meaningless to recalculate the evacuation time in consideration of the design defects of the stand. The secondary fire disaster is inevitable in theory due to the drastic appearance of the detained population and design defects of stand exit. Based on this, the crowd density of stands at second floor of the gymnasium, especially stand d, e and f, must be limited. The design structure of evacuation passageway in the middle of three stands in d, e and f must be reformed to avoid the design of the staircase structure and the corner structure. It is possible to reduce or eliminate all kinds of casualties caused by fire in a storehouse 1 at the first floor by strengthening the evacuation training for relevant personnel.

5. Conclusion

Although the computer simulation technology has been widely used in the field of evacuation research in gymnasium and other buildings in recent years, the mathematical analysis method, as the basis of the computer simulation technology, is still an important field in the study of building evacuation. Combined with the characteristics of primary fire disaster and secondary disaster of the buildings, this paper studies the crowded evacuation of the gymnasium in engineering case under simulated fire conditions by key node method and travel time method, and discusses the influence of interaction between the structural design of multi-functional gymnasium and the primary disaster and the secondary disaster on evacuation according to the performance-based evacuation design, Accident Causation Sequence Theory and cluster flow theory and other research results in consideration of relevant factors. In this research, the derivation formula of correlation model has been integrated and the relationship between the parameters of the evacuation model of the gymnasium has been clarified. Simultaneously, the relevant parameters are calibrated, and the practical application requirements of various parameters are fully considered. The research results can not only provide reference for the actual building design and reconstruction of the multi-functional gymnasium, but also guide the evacuation of the managers in gymnasium, so as to provide computing equipment for avoiding the accident arising from space-time meeting due to various risk factors. The last point to emphasize is that, the human factors play an important role in the process of evacuation based on people-thing-object accident model theory of human information processing. Therefore, it is important to strengthen the use of the gymnasium and fire awareness and knowledge training for the managers to reduce the probability of fire occurrence and avoid the accident caused by a person's failure to respond to an external stimulus (information).

References

[1] Y. J. Zhao, L. Wang, H. J. Wang, and C. J. Liu: *Minimum Rate Sampling and Spectrum Blind Reconstruction in Random Equivalent Sampling.* Circuits Systems and Signal Processing *34* (2015), No. 8, 2667–2680.

[2] S. L. Fernandes, V. P. Gurupur, N. R. Sunder, N. Arunkumar, S. Kadry: *A novel nonintrusive decision support approach for heart rate measurement.* Pattern Recognition Letters. https: //doi.org/10.1016/j.patrec.2017.07.002 (2017).

[3] N. Arunkumar, K. Ramkumar, V. Venkatraman, E. Abdulhay, S. L. Fernandes, S. Kadry, S. Segal: *Classification of focal and nonfocal EEG using entropies.* Pattern Recognition Letters *94* (2017), 112–117.

[4] J. W. Chan, Y. Y. Zhang, and K. E. Uhrich: *Amphiphilic Macromolecule Self-Assembled Monolayers Suppress Smooth Muscle Cell Proliferation*, Bioconjugate Chemistry *26* (2015), No. 7, 1359–1369.

[5] M. P. Malarkodi, N. Arunkumar, N., V. Venkataraman: *Gabor wavelet based approach for face recognition.* International Journal of Applied Engineering Research *8* (2013), No. 15, 1831–1840.

[6] L. R. Stephygraph, N. Arunkumar: *Brain-actuated wireless mobile robot control through an adaptive human-machine interface.* Advances in Intelligent Systems and Computing *397* (2016), 537–549.

[7] D. S. Abdelhamid, Y. Y. Zhang, D. R. Lewis, P. V. Moghe, W. J. Welsh, and K. E. Uhrich: *Tartaric Acid-based Amphiphilic Macromolecules with Ether Linkages Exhibit Enhanced Repression of Oxidized Low Density Lipoprotein Uptake*, Biomaterials *53* (2015), 32–39.

[8] W. Pan, S. Z. Chen, Z. Y. Feng: *Automatic Clustering of Social Tag using Community Detection.* Applied Mathematics & Information Sciences *7* (2013), No. 4, 675–681.

[9] Y. Y. Zhang, E. Mintzer, and K. E. .Uhrich: *Synthesis and Characterization of PEGylated Bolaamphiphiles with Enhanced Retention in Liposomes*, Journal of Colloid and Interface Science *482* (2016), 19–26.

[10] N. Arunkumar, K. M. Sirajudeen: *Approximate Entropy based ayurvedic pulse diagnosis for diabetics - A case study.* TISC 2011 - Proceedings of the 3rd International Conference on Trendz in Information Sciences and Computing, art. no. 6169099 (2011) , 133–135.

[11] N. Arunkumar, K. Ramkumar, S. Hema, A. Nithya, P. Prakash, V. Kirthika: *Fuzzy Lyapunov exponent based onset detection of the epileptic seizures.* 2013 IEEE Conference on Information and Communication Technologies, ICT 2013, art. no. 6558185 (2013), 701–706.

[12] J. J. Faig, A. Moretti, L. B. Joseph, Y. Y. Zhang, M. J. Nova, K. Smith, and K. E. Uhrich: *Biodegradable Kojic Acid-Based Polymers: Controlled Delivery of Bioactives for Melanogenesis Inhibition*, Biomacromolecules *18* (2017), No. 4, 363–373.

[13] N. Arunkumar, V. Venkataraman, Thivyashree, Lavanya: *A moving window approximate entropy based neural network for detecting the onset of epileptic seizures.* International Journal of Applied Engineering Research *8* (2013), No. 15, 1841–1847.

Received May 7, 2017