FIRE SAFETY DESIGN OF SPORTS GROUNDS IN HONG KONG

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ABSTRACT

The fire safety design for sports grounds should include a number of considerations that are not normally required in conventional buildings. In Hong Kong, the prescriptive fire safety codes do not address large sports grounds specifically. The most relevant requirements can be found in the "Places of Public Entrainment" (PPE) section under the relevant codes and ordinances. Meanwhile, the codes in Hong Kong also allow the use of fire engineering and performance based design.

As such, the use of performance based fire safety design is almost inevitable in modern sports grounds design since they do not always fall within the prescriptive code requirements. Computer modelling of crowd movements can be useful tools to form part of the fire engineering assessment.

This paper attempts to conduct an extensive Hong Kong code review with regarding the fire safety of sports grounds design and management. Relevant code requirements are extracted and discussed. The use of performance-based approach is also discussed; in particular, the important elements while conducting a Qualitative Design Review (QDR) for sports grounds.

A case study in Hong Kong is then presented and discussed in order to demonstrate how the fire engineering approach is adopted in parallel with the prescriptive code design in Hong Kong.

KEYWORDS: Sports grounds**,** Fire engineering approach**,** Fire safety, Hong Kong, Prescriptive code

INTRODUCTION

The fire safety design for sports grounds includes a number of considerations such as a large number of spectators, appropriate means of egress and escape, and large crowd behaviour. These unique features combined with modern complex architectural design of sports grounds present a challenge for designers who aspire to develop large sports grounds that are elegant, well-functioned, fire safe and cost effective.

Prescriptive fire safety design following strict code recommendations are the traditional method for fire safety design. Prescriptive codes are usually generic and are most suitable for typical building design. Designers can readily adopt the prescriptive solutions without the need to conduct complex engineering assessments. However, it is also well recognized that the prescriptive approach can be restrictive and may not address all aspects of fire safety when the design is complex and unique.

As a result, there is a need to use performance based design approach in fire safety design and such use has been enabled by the fire engineering knowledge and computer modeling capability being developed in recent years.

This paper has been written with three objectives in mind:

a. To research applicable fire safety codes for the design of sports grounds in Hong Kong and list out all sports grounds specific requirements. Since there is not a single document that collects all prescriptive requirements for sports grounds, this will enable designers to understand collectively the restrictions present ahead while planning their sports ground design.

b. To describe the use of performance based fire safety design for sports grounds, in particular the important elements that should be considered while conducting the Qualitative Design Review (QDR) at the beginning. This paper does not intend to describe fire engineering assessments in details, but rather, present the conceptual approach and discuss the pros and cons for adopting performance based design.
c. To present a case study for a sports ground design in Hong Kong. Performance based design has been partly adopted for specific areas where the design cannot meet the prescriptive code requirements.

HONG KONG CODE REVIEW

In Hong Kong, the prescriptive fire safety codes do not always specifically address sports usages. The relevant requirements are scattered in various documents. In other words, there is not a single document that collectively describes all prescriptive fire safety requirements. Designers will have to refer to prescriptive codes that provide guidance for general buildings, assembly buildings, places of public entertainment and other areas.

An extensive Hong Kong Code review has been conducted. The scope includes the review of fire-safety relevant recommendation and requirements as stipulated in relevant Hong Kong Regulations, Buildings Department's Codes of Practice and Practical Notes, Fire Services Department's Codes of Practice, Circular Letters and Fire Safety Requirements for PPE Licence. The following documents are found to be the latest relevant ones:

a. Chapter 123 - Building Ordinance [1];
b. Chapter 172 - Places of Public Entertainment Regulations [2];
c. Code of Practice for Means of Access for Firefighting and Rescue (MoA Code) [3];
d. Code of Practice for Provision of Means of Escape in Case of Fire 1996 (MoE Code) [4];
e. Code of Practice for Minimum Fire Service Installations and Equipment (FSI Code) [5];
f. Code of Practice for Fire Resisting Constructions 1996 (FRC Code) [6];
g. PNAP 194 – PPE Regulations 1996 [7];
h. PNAP 204 – Fire Engineering Approach [8];
i. PNAP 288 – Emergency Vehicular Access (EVA) [9];
j. FSD Circular Letter – 1/2000 [10];
k. FSD Circular Letter – 2/2001 [11]; and
l. Fire Safety Requirements for PPE (other than cinemas & theatres).

The most specific requirements to sports grounds, as stipulated in the codes and regulations, are under the section called "Places of Public Entertainment (PPE)". Although specific to sports grounds, it should be noted that the PPE requirements are also applicable to other large crowd venues such as theatres, cinemas, conference centres and conventional centres.

The similarity for this type of building is that they are likely to accommodate a large number of people. However, the codes and regulations do not distinguish fire safety design for indoor, semi-open and totally open venues. The fact is that the fire and smoke behaviour can vary significantly depending on the openness of the building. In addition, the behaviour of occupants can also vary significantly between large crowd venues.

General Design Requirements Specific for Sports Grounds in Hong Kong

In Hong Kong, there are statuary requirements on building design and construction. Such requirements can be found in Chapter 123 of the Hong Kong Law – Building (Planning) Ordinance. This chapter gives the general planning, design and construction requirements on sites and buildings. Particularly, the designer may refer to Chapter 172 of the Hong Kong Law - Places of Public Entertainment Regulations. This chapter gives specific requirements on planning, design, construction

and building management requirements on places of public entertainment. As the sports ground is under the category of places of public entertainment, the design may also refer to this Chapter for the general design for sports grounds.

Separation from other structure

For temporary structures of the places of public entertainment, the PPE Ordinance requires the structures should be at least 9 m away from any other structure. From the aspect of fire safety, separation between two buildings or structures aims to decrease the likelihood of fire spread between the buildings through unprotected openings.

Permanent seating

Similar to other international guidelines for sports ground, there are requirements of permanent seating for the places of public entertainment. According to the Regulation 37 of PPE Ordinance, the seating area assigned to each person shall be not less than-

a. 700 mm deep where backs are provided; or
b. 600 mm deep where backs are not provided; and
c. 500 mm wide where arms are provided; or
d. 450 mm wide where arms are not provided.

In all cases there shall be an unobstructed way or space at least 300 mm in depth, measured between perpendiculars, between the back of each seat and the front of the seat immediately behind it which means 300 mm clearways should be provided for normal egress and emergency evacuation.

In addition, the seating shall be fixed firmly to the floor. If seats are made to tip up automatically they shall be actuated by weights.

Boxes

Boxes design is allowed in the spectator stand design. In Regulation 52 of the Places of Public Entertainment Ordinance, the requirements of boxes design are that the sides of any boxes which may be provided shall not exceed 900 mm in height and the fronts of the boxes shall be formed with open balustrades or grilles. In addition, curtains shall not be provided to boxes and recesses shall not be obscured by curtains.

Floors and tiers

Requirements of floor and tier planning of the spectator stand are stipulated in the Subsidiary Legislation of Building (Planning) Regulations of the Hong Kong Law (Chapter 123). Part VIA of this Regulation is designed for places of public entertainment. The Regulation 49D – Floors and tiers states clearly that each floor or tier shall be constructed so that it does not have a gradient steeper than 35 degrees to the horizontal. In addition, the height between any such floor or tier and the underside of the tier or floor above it shall in every part be at least 3 m.

Means of Escape Requirements Specific for Sports Ground in Hong Kong

Due to the impact of large crowds on fire safety, means of escape design is most critical in large sports grounds. In Hong Kong, the prescriptive design requirements of means of escape provision for a sports ground is mainly described in the Code of Practice of Means of Escape Provision in Case of Fire (MoE Code), much of which focus on the design of tiered seating. In general, the code has requirements on design of means of escape provisions such as clearways, gangways, exitways, exit doors, stair ways and thoroughfares.

Stair tread and riser

Similar to other codes of practice, there are specific requirements on stair treads and risers of staircases. In Hong Kong, the specific requirements are stipulated in Paragraph 17.2(b) of the MoE

Code. For places of public entertainment, threads should be not less than 280 mm wide and not more than 150 mm high.

Gangway

The MoE Code has specific requirements for the design of gangways for places of public entertainment, including sports grounds. The maximum allowable distance between two gangways is 6 m. The intention of the design is to limit the maximum travel distance between any part of the seated area between the gangways, to ensure that occupants evacuate from the danger within a reasonable time.

Exit route

The MoE Code has prescriptive requirements on the width of each exit route. Paragraph 25.3 of the MoE Code states that if the tier or floor is capable of accommodating not more than 300 persons the width of each exit route should be not less than 1.2 m. If the tier and floor is capable of accommodating more than 300 persons the width of each of the exits should be not less than 1.5 m. The distance should be measured between the walls at any point or between the leaves of doors when open. The intention of this Paragraph is to ensure sufficient evacuation capacity for spectators to leave the tier or floor of fire within a reasonable time limit. Paragraph 25.4 of the MoE Code further considers the impact of building height to the means of escape provision. This paragraph states in the case of any places of public entertainment or portions thereof which are 12 m or more above pavement level, the total width of exit routes should be 25% in excess of the width required by Paragraph 25.3. The intention of this requirement may primarily be aimed at venues within a multi-storey complex such as a cinema. This type of building is usually enclosed and located at the higher levels of a large multipurpose complex, where there may be multiple shows at one time and phased evacuation may be adopted. As such, the same requirements may not be significant to open or semi-open type sports grounds where all audiences focus on one event at one time.

Thoroughfare

Under the MoE Code, the site of a place of public entertainment should abut upon and have frontage to two or more thoroughfares. The thoroughfares should be sized to suit the number of people expected on the site. The requirements are stipulated in Paragraph 22 of the MoE Code.

Additional exit capacity

The MoE Code also concerns buildings having occupant capacity over 10,000 in a prescriptive way. Paragraph 15.8 of the MoE Code states that the total width of staircases of a building should be enlarged by 20%. The code does not offer reasons or justifications for such an allowance. In addition, Paragraph 15.9 of the MoE Code suggests that the fire engineering approach may be the only viable means to a satisfactory standard of fire safety for venues with a holding capacity or 10,000 or more.

Means of Access of Fire Fighting Specific for Sports Grounds in Hong Kong

The means of access of a building is one of the most important fire safety considerations for sports grounds as the potential number of lives at risk is large. Appropriate design and construction of means of access enable the fire-fighting brigade to perform effective rescuing and fire-fighting. In Hong Kong, the requirements of the provisions of means of access of building are stipulated in the Code of Practice for Means of Access for Firefighting and Rescue (MoA Code), which is issued by the Buildings Department.

However, the MoA code does not ask for provisions specific to sports grounds or any other venues with large crowds. In essence, it gives guidance to include the following provisions which is general to all building types and related to building heights and size.

a. Access staircase
b. Fireman’s lift

c. Emergency vehicular access

Fire Resisting Construction Specific for Sports Grounds in Hong Kong

The intention of providing fire resisting construction for buildings is to provide protection from the effects of fire by inhibiting the spread of fire from one fire compartment to another and ensuring the integrity of the structural elements of buildings. In Hong Kong, the Code of Practice for Fire Resisting Constructions 1996 (FRC Code) issued by the Buildings Department provides statutory requirements of fire resisting construction for buildings.

Similar to the provision of MoA code, the FRC code does not provide guidance specifically for sports grounds. The requirements are generic in limiting the compartment size and stating the fire resisting period for the elements of construction.

Roof

Under the definition of FRC code, the roof supporting its own weight only is not considered as an element of construction. The code requires the roof to be constructed of non-combustible material and it is not required to have a fire resistance period except for single stair buildings with a floor above 13 m. With modern sports grounds design, the roof is often an important feature and the design can often be unique, fancy and lightweight. The roof structure provides shelter to a significant amount of the crowd in a large sports ground. It is important to prevent progressive collapse in the event of a fire as the consequences of such a failure can be catastrophic.

Fire Protection System Requirements Specific for Sports Grounds in Hong Kong

In Hong Kong, the provision of minimum fire services installations and equipment for building is governed by the FSI Code of the Fire Services Department. The FSI Code has a list of classification of premises and areas of special risks for designers; however, there is not any class for places of public entertainment or sports grounds. In common practice, the provision of minimum fire services installations should be discussed with the Fire Services Department with the considerations of anticipated fire hazard, fire risk, number of occupants and building design.

Design Consideration for People with Disabilities

Part V of the Commentary Part of the MoE Code declares that the Code does not cover the provisions of means of escape for people with disabilities. However, the same part of the Code recommends the designers to consider such provisions by referring to BS 5588 Part 8. It continues to state that as a minimum provision, a communication panel may be installed adjacent to the fireman's lift as a call point for help for people with disabilities in case of fire.

Fire Safety Management Requirements

Fire safety management is one of the most important elements in fire safety design of sports grounds with large crowds.

Fire safety management shall include staff training, development of fire action contingency planning, routine fire precautions, housekeeping, and security.

In Hong Kong, the statuary requirements tend to focus on maintenance on fire safety installations.

Maintenance

According to the Fire Services Department's requirement, the fire service installations for a building must be maintained, inspected and certified by a registered fire service installation contractor at least once every 12 months. Another requirement is in Regulation 7 of Chapter 172A – PPE ordinance

states that all parts of the premises and the fitting and apparatus therein, such as door fastenings, notices, lighting and other services installations shall be maintained at all times in good order and condition and as approved by the licensing authority. The Regulation further states that any alterations or additions whether permanent or temporary to the structure, the services installations, the seating, gangways or other installations approved by the licensing authority from time to time, shall not be made except with the consent in writing of the licensing authority.

PERFORMANCE BASED FIRE SAFETY DESIGN FOR SPORTS GROUNDS

After reviewing the prescriptive fire safety codes and regulations in Hong Kong, it is obvious that the codes do not specifically mention sports grounds. Instead sports grounds are categorised generally under "Places of Public Entertainment". As such, the same set of guidance is applicable to sports ground and other public assembly buildings. Therefore, the use of the performance-based approach is even more important to be adopted as it can be proven to be more flexible and sometimes more appropriate especially for large and complex sports venues.

There are a number of documents written to provide guidance for using a performance-based fire engineering design. One of the most significant ones is the BS7974 series. The process described within the document is clearly defined as an interactive process. Fig. 1 below shows the flow chart extracted from BS7974.

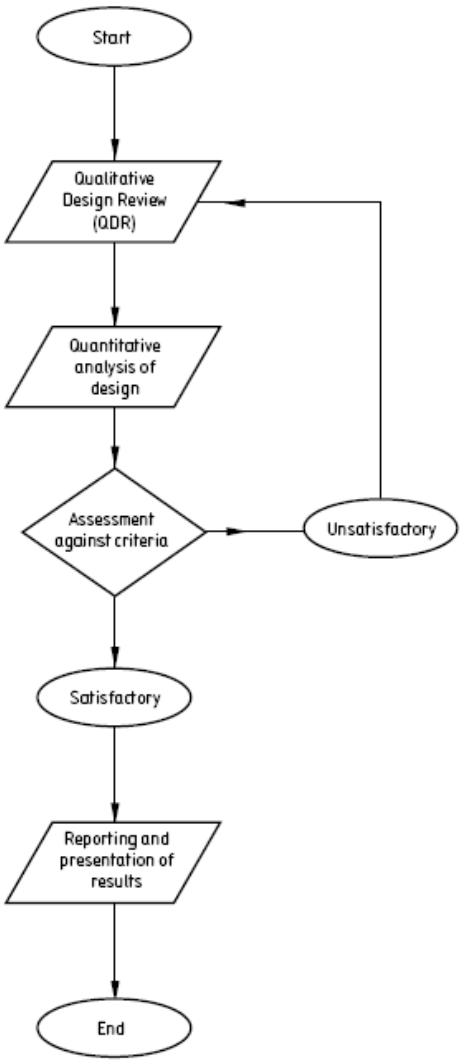

FIGURE 1. Fire safety design process from BS 7974 [12]

Qualitative Design Review (QDR) for Sports Grounds

Qualitative Design Review (QDR) is considered to be the most important part throughout the performance based design process. It should include a review of the overall design as a whole, identification of any overriding constraints and definition of the design objectives. Quantification will normally only follow when the design parameters have been established. Fire engineering quantifications range from simple calculations to detailed analysis using complex tool such as Computational Fluid Dynamics (CFD), people flow modelling and finite element analysis. However, these quantifications can become emaciated if the QDR has not been established properly. During the QDR process, the scope and objectives of the fire safety design are defined, performance criteria are established and one or more potential design solutions (trial designs) are proposed. Key information is also gathered to enable detailed evaluation of the design solutions in the quantitative analysis. The key considerations are listed below when conducting a QDR for sports grounds:

Building enclosure

Sports grounds can be of open, semi-open or indoor type. The type of enclosure will significantly affect the fire strategy developed for the building. Smoke can be of great threat in the event of a fire for indoor sports buildings with large number of spectators, which open stadia are less likely to encounter.

Size and geometry of venues

The size of sports ground is usually larger than conventional buildings due to the nature of their use. Large volumes perform better in the event of a fire in term of smoke and heat. It takes longer to reach non-tenable conditions and hence it is possible to allow a longer evacuation period. Special consideration has to be given to tier seating where the highest occupied level is near the ceiling and occupants at the top tier will have to be given priority for escape considerations. There may also be exceptions for certain types of venues such as squash centres where vertical walls are installed at frequent intervals, rather than providing a large open space.

Use of sports grounds

The type of sports held within the sports grounds will lead to different types of risk. For example, the type of crowd pattern will be different for football venues than for horse racing venues. Consideration has to be given to whether the building is used for non-sports event as well such as conferences and exhibitions. Such events are likely to have small parts of the building occupied to a high level of density while other parts are unmanned.

Source of fire

The quantity of fire load present in sports grounds are usually low compared to other types of buildings. Some sports buildings such as swimming centres will have virtually zero fire load within the spectator and public areas. Special relaxation may be appropriate for this type low fire risk venues.

Smoke management system

Smoke management system is often needed for indoor buildings to maintain tenability within a large capacity of crowds. Similar considerations may need to extend to semi-open buildings. The decision to adopt either mechanical or natural smoke extraction systems can also play a major part of the fire safety strategy.

Evacuation time

The time to untenable condition, as mentioned earlier, very much depends on the size of the space. Combined with an appropriate smoke management system, a smoke layer can be maintained at high levels for steady state conditions. Such tenability can be maintained for an indefinite period. This is often achievable for sports grounds with large volume or are open/semi-open. However, it does not necessarily mean that the evacuation time can be extended indefinitely. Other factors might play

the critical role rather than tenability. The Guide to Safety at Sports Ground [13] published in the UK indicates that queuing is a major factor to consider during evacuation. Occupants are more likely to be agitated after queuing for more than 8 minutes. Therefore the same guide limits the egress and emergency evacuation time in sports grounds to a maximum of 8 minutes. This limit is applicable to all types of sports grounds. Further research on crowd behavior may be necessary as spectators may behave differently for different sports, different environments and in different countries.

Discount of exits due to fire and crowd pressure

While calculating evacuation as part of the Required Safe Egress Time (RSET) and Available Safe Egress Time (ASET) assessment, it is necessary to consider whether to discount exits, and if so, how many exits at what locations are discounted at one time. With a large number of spectators within the sports grounds, crowd pressure can be a potential issue and it may not be appropriate to ask the spectators to turn around after they have entered a perceived escape route. Crowd pressure from the back may not allow such a radical change of direction to take place. Therefore it may be necessary to design out a fire completely at appropriate locations rather than simply discounting such exits.

Structural Fire Behaviour

The structural design of a sports ground often requires a large column free space for sports activities. This often results in a more complex structural form. Where large numbers of spectators are involved, it is also important to provide column free space to allow maximum sightlines. For these reasons, the structural fire behavior requires careful consideration. The prescriptive solution to simply protect all elements of structure to the same fire resistance period is too simplistic. Often large spaces are provided below a roof and structural elements supporting the roof only are not required to be protected. The adequateness must be checked against progressive collapse if the whole roof is interconnected. On the other hand, large spaces are less likely to be heated up to a critical level affecting structural behavior. This is because flash over is unlikely to occur within large spaces especially when the fire load is relatively low. All these factors must be considered as part of the structural fire performance assessments.

Available fire safety management

Fire safety management is considered an essential part of the fire safety design, which is intended to both minimize the incidence of fire and to ensure that, when a fire does occur, the installed fire safety systems (including active, passive, and procedural systems) are in place and are fully functional to control the fire growth and fire spread. The management of fire safety is an essential element in averting disaster in the event of a fire, especially with the presence of large crowds that are focused on the sporting events and may not be aware of potential incidents. The fire safety management should at least include a maintenance plan, a staff training plan, and a fire action plan.

Other considerations

There are many other items which may require consideration when conducting a QDR for sports grounds. They include the consideration of the impact of spectators' behavior (e.g. effects by alcohol), evacuation for disabled people, combination of fire incidents with other extreme events and many others. Each large sports grounds shall require individual merit in developing the QDR.

CASE STUDY

This section describes a recently completed project in Hong Kong where fire engineering assessments were conducted on a sports ground. The full performance-based approach has not been adopted throughout the project because the design can meet most parts of the prescriptive code, except for the means escape design as a place of public entertainment. Therefore the fire engineering assessment focused on the egress of the sports ground.

It should be noted that this type of approach is most common at present in adopting a fire engineering approach in Hong Kong. The Authorised Person (AP) of the project has the obligation to check and

design the building to meet code requirements. When certain areas of the design cannot readily meet the prescriptive codes, the AP will usually ask a fire consultant to propose an alternative solution. It is specifically written in the prescriptive codes in Hong Kong that alternative solutions can be adopted instead of following the code solutions. The fire consultant will then develop the fire engineering solutions, document it and present to an expert panel within the Hong Kong Buildings Department (i.e. the Fire Safety Committee) for approval. Each of the fire engineering studies will be assessed individually. This process has been undertaken for the case study described below.

Project Description

The proposed sports ground is a new semi-open sports ground for the East Asian Games taking place in 2009. It consists of a pitch, a main spectator stand, a practice pitch and other functional rooms. The main spectator stand is the subject of study in this project. It is open at all four sides and covered with a roof for weather protection. The design seating capacity is approximately 4,900.

In Hong Kong, sports grounds where members of public can gain access to are considered as places of public entertainment (PPE). Other places of public entertainment include cinemas, theatres and dance halls. All PPE buildings will have to be designed to meet additional requirements under the prescriptive codes.

The design of the sports grounds deviates from the prescriptive code requirements under Means of Escape and PPE. The deviations include the gangway separation, the stair widths and the travel distances within the main spectator stand. A fire engineering study has been conducted to demonstrate that all spectators can evacuate from the spectator stands within an acceptable time limit although the design does not readily meet the prescriptive code.

The code provides a prescriptive solution to fire safety design but it is not building specific. Although sports grounds are under the category of PPE, the code's requirements are not building specific. In this case, the main features of the sports ground is a semi-open environment and the nature is rather different to other PPE buildings such as cinemas and theatres.

The Approach

The main spectator stand of the sports ground is a semi-open and naturally ventilated space. The roof is up to 18 m above the lowest tier of the seating. After conducting qualitative fire load assessment and smoke fill calculations, it was demonstrated that members of public at occupied levels will not be affected by smoke for a prolonged period. This is not unusual due to the openness of the spectator stand and the limited amount of combustibles available within the stand. It should be noted that accumulation of rubbish within the stand is not allowed and regular cleaning and rubbish collection has been built into the operation management of the sports ground.

The study then focused on the evacuation of the main spectator stand. The Guide to Safety at Sports Grounds published in the UK has been referred to for the fire safety design. The evacuation time, in particular, mentioned in the guidance has been adopted as the acceptance criteria for the evacuation analysis conducted for this project. The evacuation time is an estimated time for the last spectator to evacuate to places of safety. Using the criteria given in the Guide to Safety at Sports Grounds, spectators shall reach a place of safety with 8 minutes for low fire risk venues. It should be noted that the limit of eight minutes is a period where spectators are less likely to become agitated, or experience frustration or stress, provided they enter an exit system at an acceptable rate and/or can identify their point of exit. It is not a limit directly relevant to fire safety. In this project, the protected staircases and open sky spaces have been defined as a place of safety where occupants can reach within 8 minutes.

Due to the number of spectators and complex inter-queuing phenomena between all exitways, gangways and exits, computational evacuation simulation has been adopted to calculate the evacuation time. The computer software Simulation of Transient Evacuation and Pedestrian MovementS (STEPS) [14] has been adopted for the analysis.

The evacuation simulation comprises of building geometry, evacuation model and modelling parameters such as number of spectators, distribution of spectator groups, walking speed of spectators in the event of emergency, and spectators' body dimension.

Results in both numerical and graphical formats are obtained. Queuing phenomena around the exits is observed and analysed and the evacuation time is determined. Figs. 2 to 4 below show the snapshots taken throughout the simulations at different time intervals. Separate analyses were conducted assuming all exits being available and the largest exit being discounted due to fire.

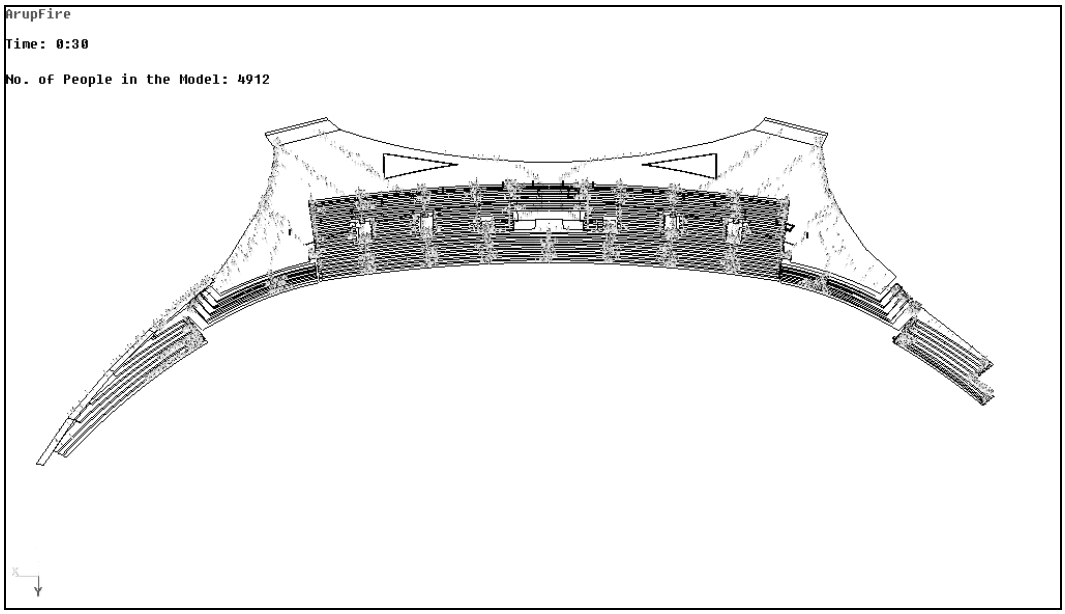

FIGURE 2. Snapshots from computational evacuation simulation at t = 30 sec

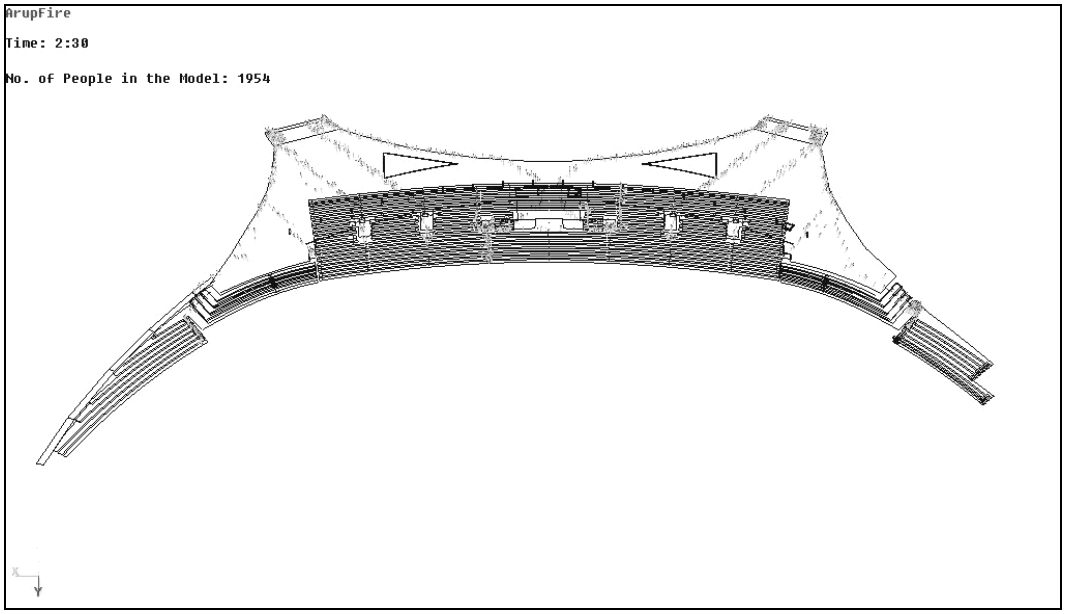

FIGURE 3. Snapshots from computational evacuation simulation at t = 150 sec

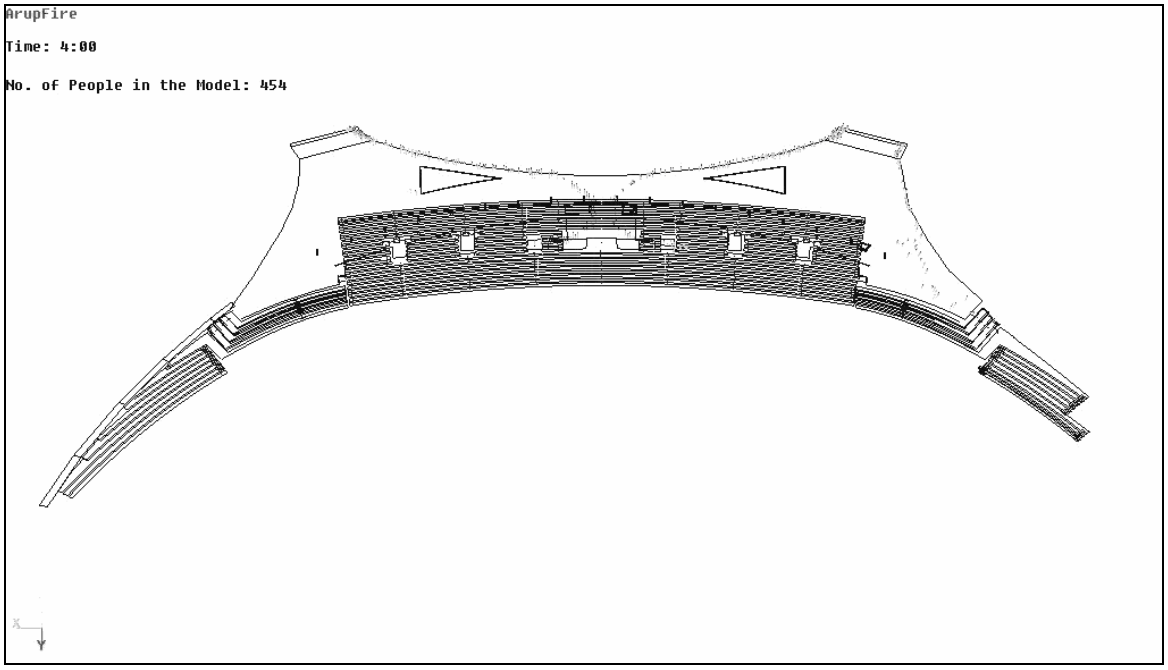

FIGURE 4. Snapshots from computational evacuation simulation at t = 240 sec

Results Discussions

It is found from the evacuation analysis that queuing occurs in front of every entry of the exit staircases of the spectator stand. Spectators may queue in front of the staircases for up to 2 minutes before entering the staircase exits. Although queuing also occurs at the conjunction of each gangway and exitway, the queuing time in front of staircase exits is significantly longer than that of queuing in front of the gangways. It was concluded that queuing contributes most of the evacuation time in the analysis.

On this basis, it was demonstrated that both the gangway separation and the travel distance are not critical elements affecting the evacuation time. The simulations also show that the evacuation time is inside 5.4 minutes even when the largest exit is discounted (compared to 4.1 minutes without discount) which is within the acceptance criteria.

A fire safety management plan for the sports grounds was also outlined as part of the fire engineering study. Fire safety management has been emphasised as one of the most important elements in fire safety design, especially with sports venues, due to the large number of people and varying activities.

CONCLUSION

Although prescriptive fire safety codes are simple and convenient for designers to adopt for building design, it has been demonstrated in this paper that they cannot often cover all aspects in detail. Often large and complex buildings such as sports grounds cannot readily meet the codes. Performance based fire engineering design can be introduced to demonstrate that the fire safety objectives are achieved despite having deviations from prescriptive codes.

When a performance based approach is adopted, it is important to conduct a comprehensive Qualitative Design Review in order to consider the issue as a whole and identify any overriding constraints and definition of the design objectives. Quantitative analyses can then be conducted to verify whether the acceptance criteria for the design are met. The important elements for QDR have

been discussed in this paper. The case study aims to demonstrate the application of fire engineering in the means of escape design of a sports ground in Hong Kong. It was shown that the occupants can escape safely in the event of a fire and the overriding factor is the queuing effects. The design may be further refined, if so desired, focusing on the alleviation of massive queuing. Fire safety management was also highlighted as an important element forming part of the design.

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