HOW FIRE ENGINEERING ENABLED THE DESIGN OF A STATE OF THE ART REGIONAL SPORTS FACILITY

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1.0 INTRODUCTION

In early 2009 North Lanarkshire Council in partnership with Ravenscraig Ltd and Sports Scotland started work on a new £30m Regional Sports Facility on the site of the former steelworks at Ravenscraig, Motherwell.

Figures 1(a) Architectural Image demonstrating the design intent (Populous)

The new flagship facility is part of the National & Regional Sports Strategy that is seeing a number of ambitious sports venue projects being delivered throughout Scotland. The new facility is a crucial competition and training venue and will host local, regional and national sporting events as well as leisure and cultural events. It will be capable of accommodating 5,000 people attending concerts, exhibitions or sporting events. The facility will be used for training for the 2012 Olympics and the 2014 Commonwealth Games.

The new facility contains:-

- A full size indoor 3rd generation synthetic football pitch (105m long x 73m wide x 24m high)
- An Athletics Hall featuring track and field event training area (135m long x 26.5m wide x 11m high).
- Strength & Conditioning Area
- 9 Badminton court Sports Hall

- 2 Dance / Drama Studios
- 2 Classrooms
- Café
- Sports Injury Clinic
- Athletics Interaction Zone
- First Aid Room
- Central Changing Area
- Viewing Galleries
- Activity Area for Children
- Outdoor Football Pitches
- Jogging Track

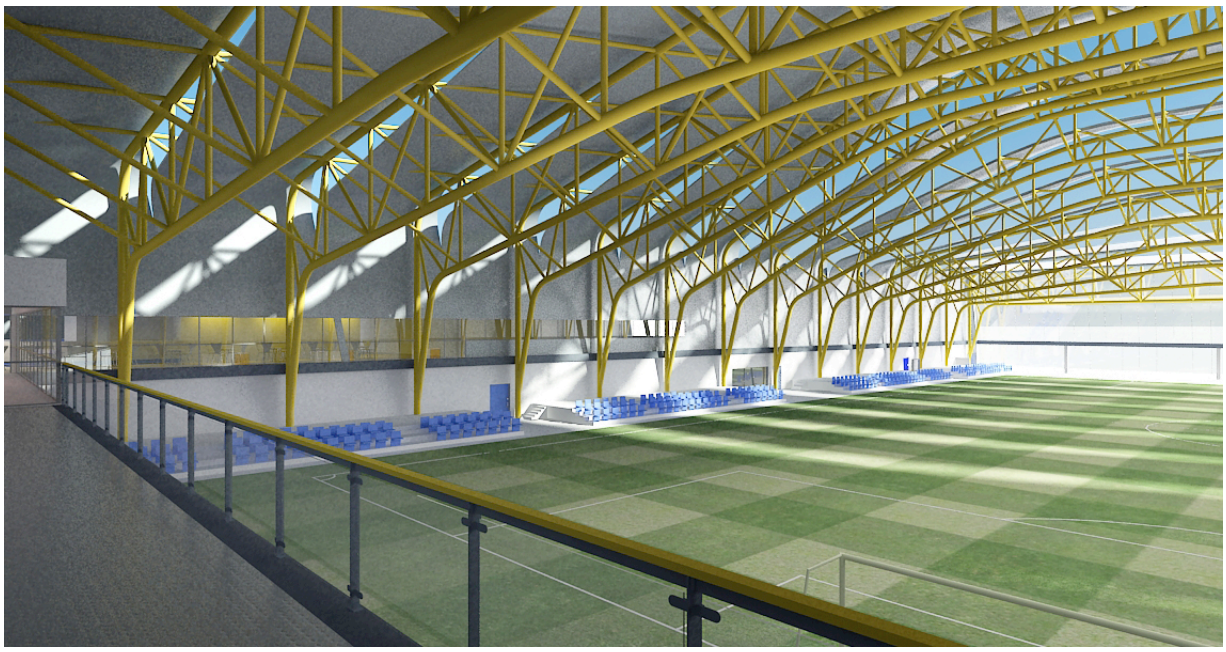


Figure 2. View in Football Hall

The main challenges for the fire engineering strategy to address and overcome were:-

1. Incorporation of the large football hall (7500m^2) which far exceeds the maximum fire compartment size permitted by Building regulations for a building of this use.
2. The proposed use of the Football Hall for events such as pop concerts where the occupancy could be as much as 5000 people.
3. Incorporation of a complex serrated roof geometry in the football hall
4. The desire for openness throughout the building to encourage interaction, wayfinding, circulation and visibility / viewing.
5. Incorporation of a double height entrance foyer space with overlooking galleries.
6. The desire to have open stairs and use of these as egress in the event of an emergency.
7. The accommodation layout does not meet many of the traditional prescriptive requirements of the Building Regulations such as travel distance, sequence of escape etc.

2.0 METHODOLOGY

Buro Happold were consulted at an early stage in the design development process and led the development of the fire engineering strategy for the complex, working closely with the client and Architects to understand the overall design aspirations and objectives.

A performance based approach was taken for the development of the fire engineering strategy in this case and Building Control and the Fire Service were consulted at an early stage and were involved/ consulted throughout the design and construction of the building. Both recognised that the proposed design did not fit with the traditional prescriptive code and embraced the proposed performance based fire engineering approach.

The development of the fire engineering strategy in this case started with a code review of the architectural proposals and identification of the areas of the planning that did not follow the recommendations of Section 2 of the Non Domestic Technical Handbook (NDTH).

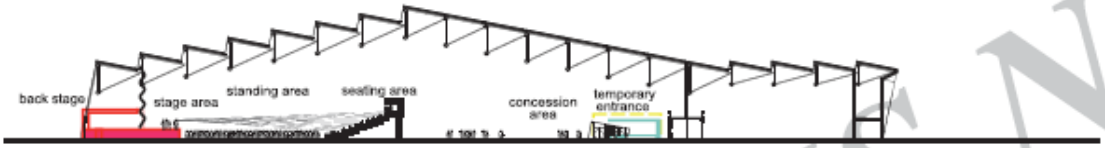
From this review a list of issues / problems to be solved was drawn up and a number of possible trial solutions identified.

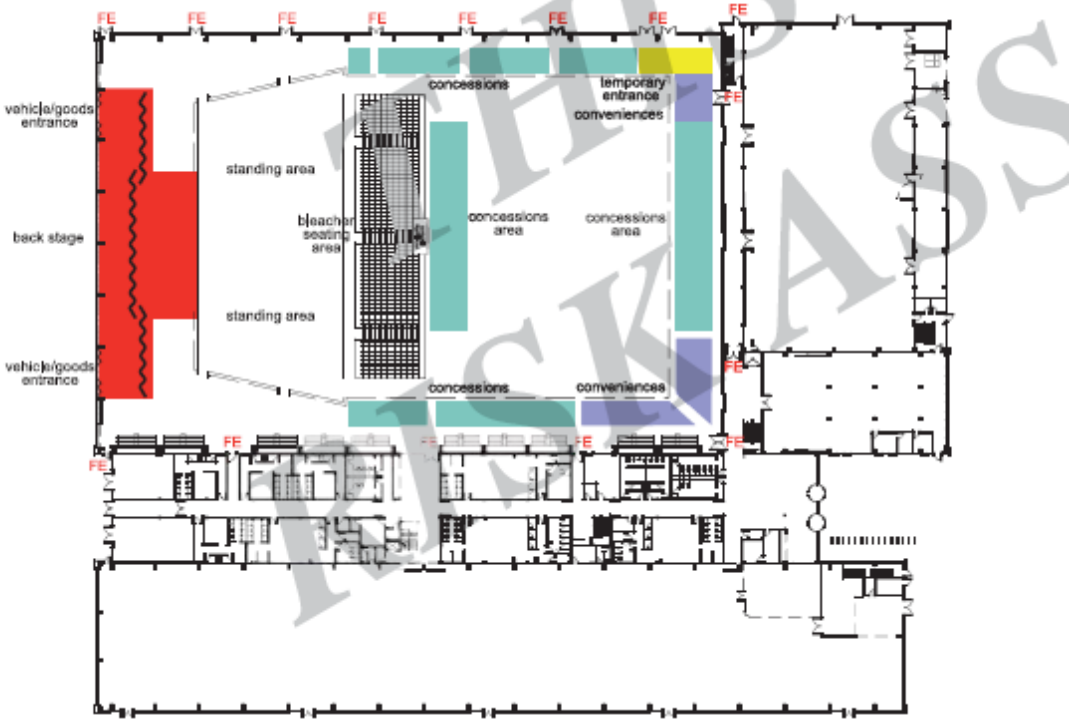
2.1 MULTI-USE OF FOOTBALL HALL

Given the size and geometry of the football hall, traditional methods of smoke control design by using hand calculations would not be applicable in this particular case. The shear size of the hall alone exceeds the maximum size of space that zone model calculations are valid for. An extensive three dimensional and physical smoke flow study was therefore undertaken utilising computational fluid dynamics to investigate actual smoke flow in the space concerned and refine the smoke exhaust design.

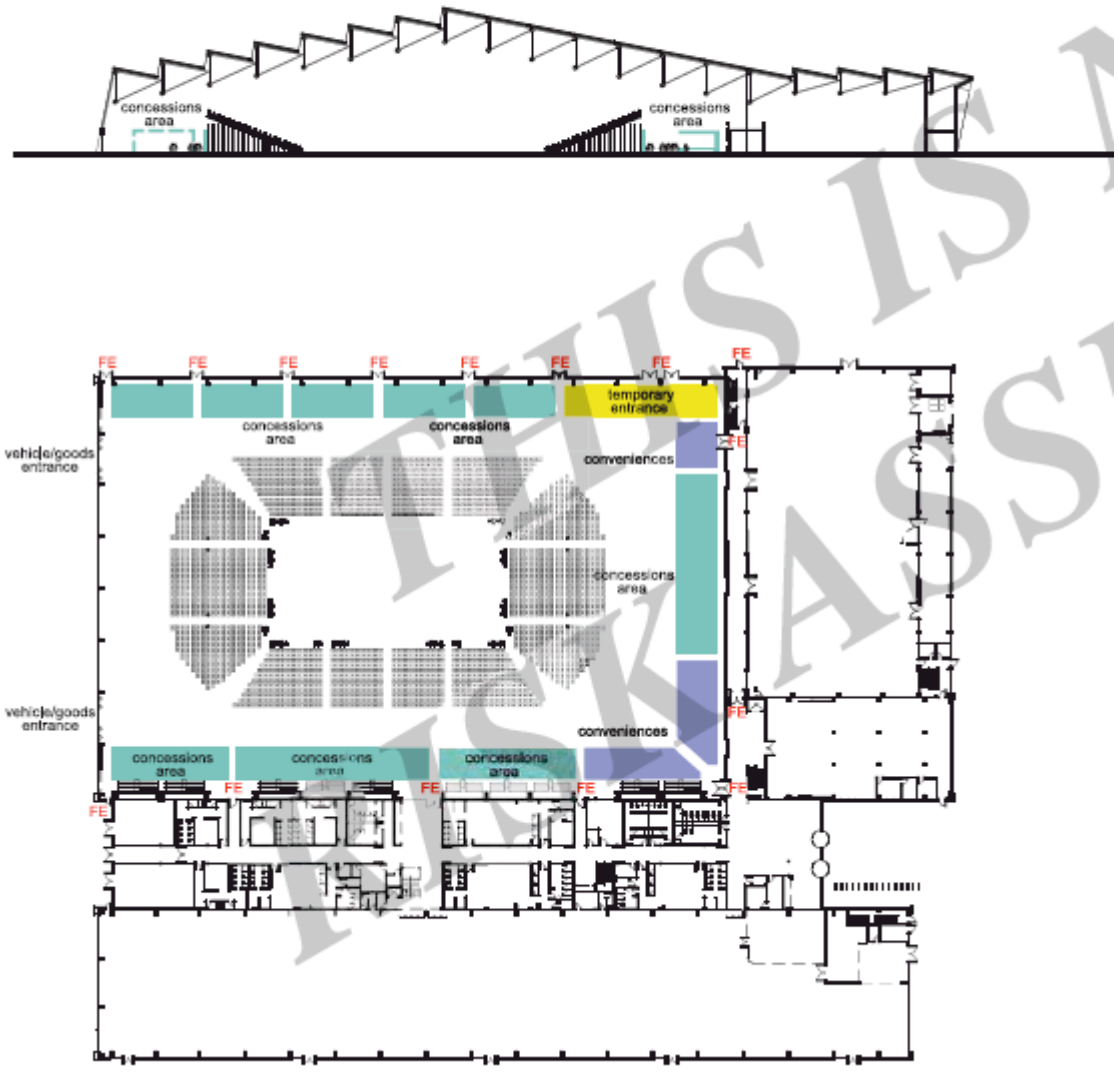
A hazard and operations study was undertaken to understand how it was planned to use the space in the future and establish credible and realistic fire scenario's to be investigated. The design team and client were involved in this process so that the assumptions that were being made matched reality. This hazard and operations study informed the CFD modelling process.

INDICATIVE TEMPORARY MUSIC EVENT PART STANDING AND SEATING

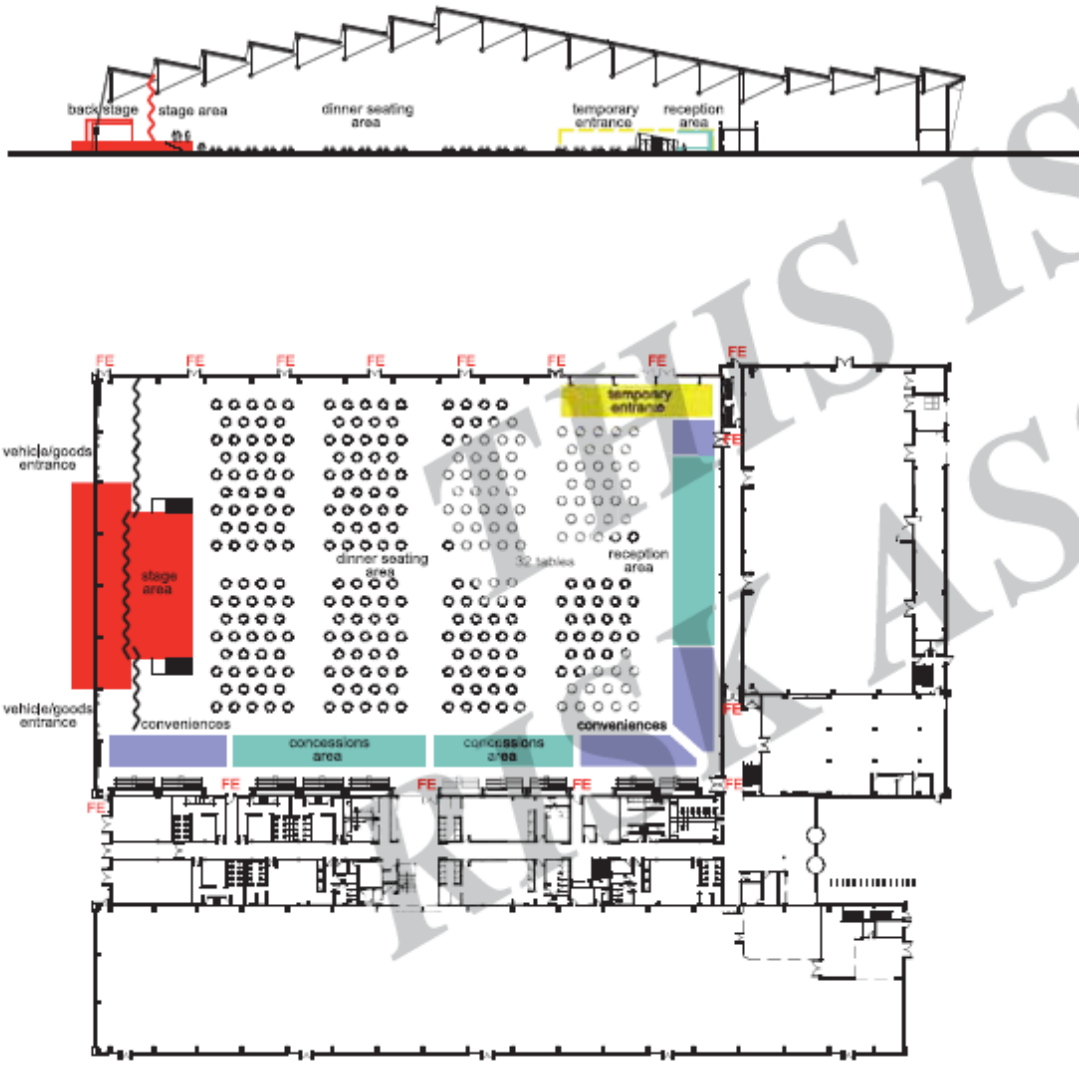




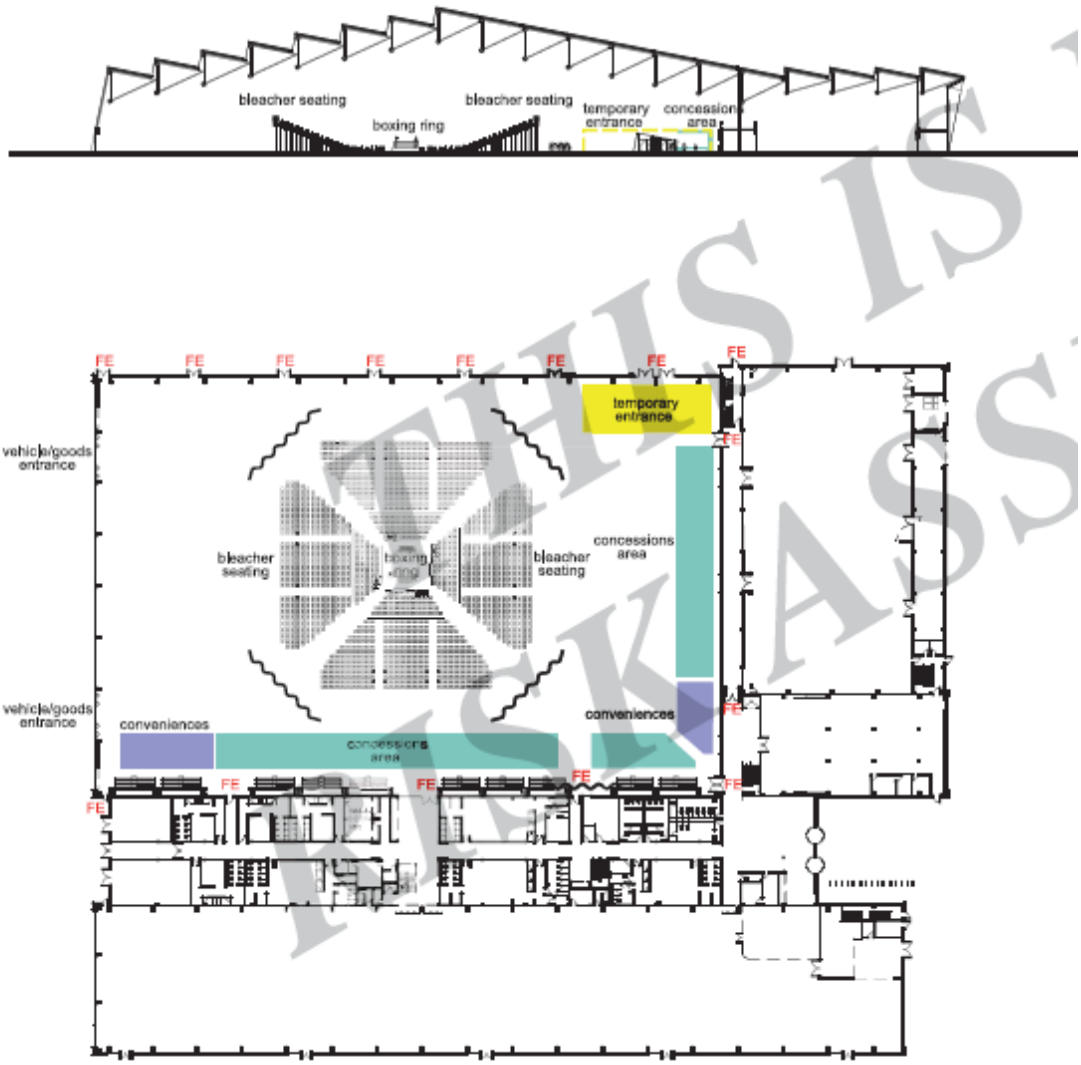
INDICATIVE BASKETBALL COURT LAYOUT WITH TEMPORARY BLEACHER STANDS



INDICATIVE DINNER EVENT WITH LARGE CIRCULAR 12 PERSON TABLES



INDICATIVE BOXING RING LAYOUT WITH TEMPORARY BLEACHER STANDS



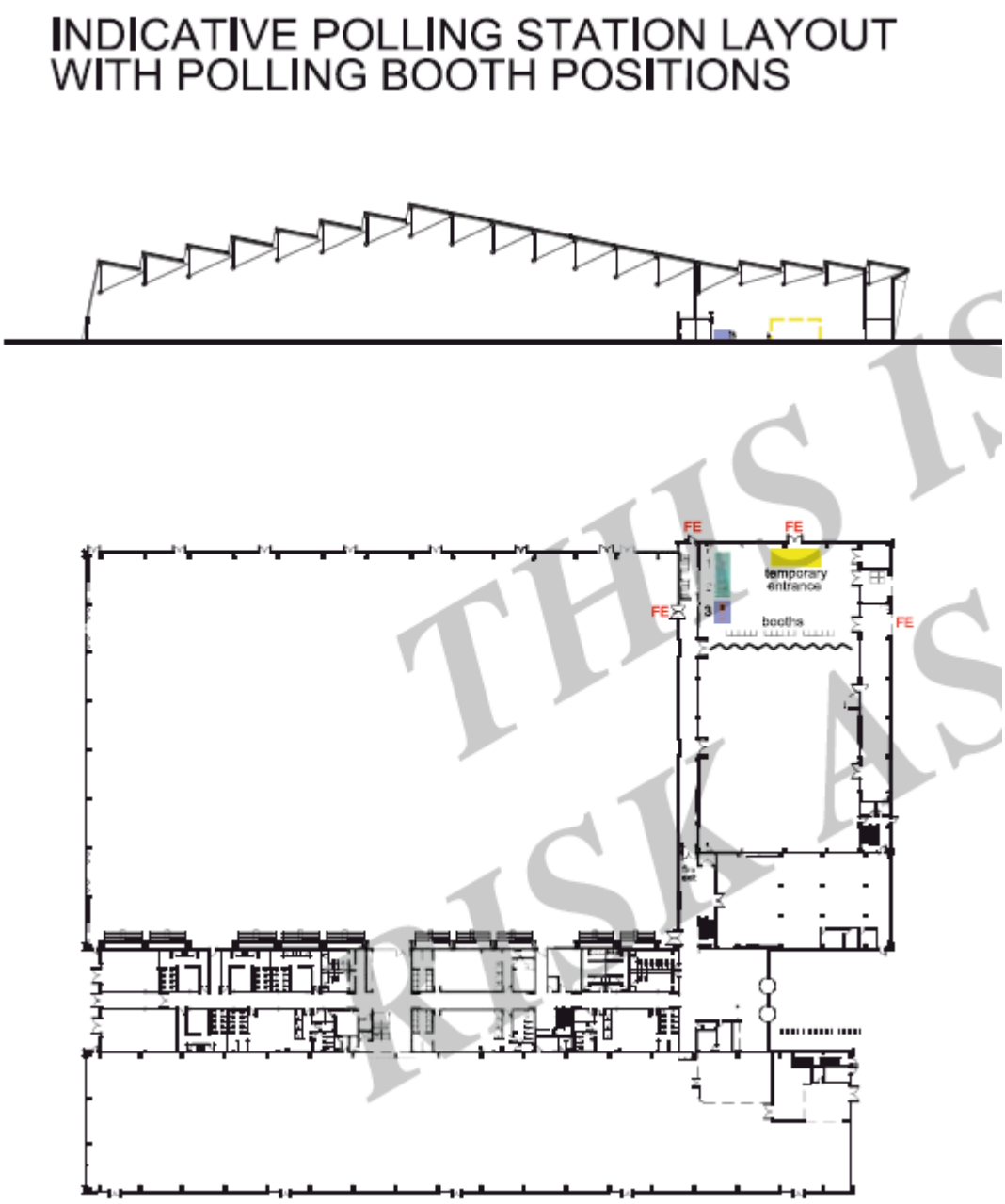


Figure 3. Proposed Football Hall Uses

The HAZOP identified a number of credible fire scenario's to be considered in detail. Fire sizes from 1Mw to 20Mw were considered and differing fire growth rates were considered. A total of 12 potential differing fire locations within the Football Hall were identified.

Figure 4. Fire Locations Studied in Football Hall

Differing configurations of smoke exhaust system were also studied. Studies looked at location of the inlet and exhaust vents as well as whether introduction of a smoke curtain to form two smoke reservoirs would influence the results.

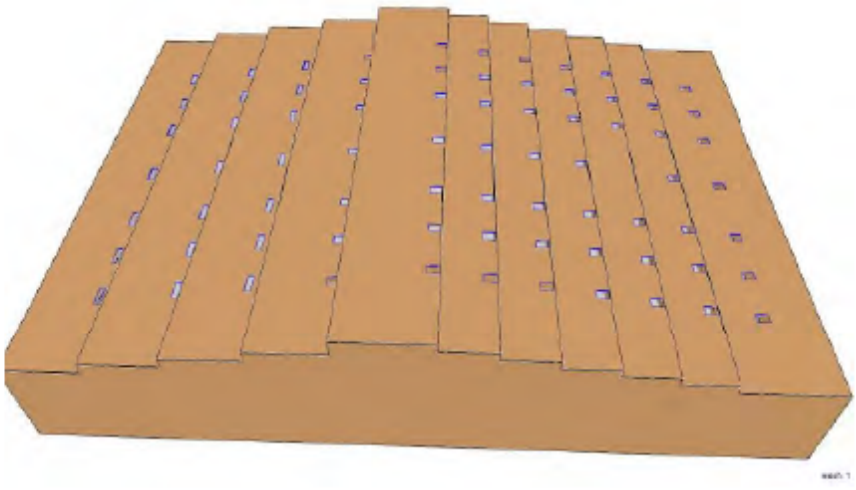


Figure 5. Exhaust Vent Locations Studied in Football Hall Roof

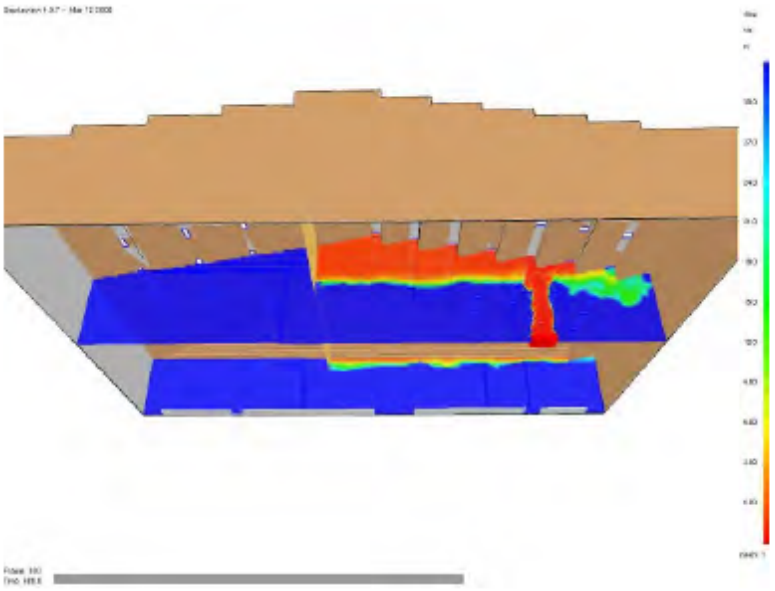


Figure 6. Results of CFD Study With Smoke Curtain Present

The results of the initial CFD simulations undertaken at Scheme Design indicated that:-

- The flow of smoke through the space was heavily dependent on the location and size of the fire.
- The flow of smoke was dependent on the materials that were burning.
- The flow of smoke through the space was seriously influenced by the geometry of the roof. This was the most important factor influencing the flow and descent of the smoke in the Hall.
- The flow of smoke through the space was affected by the size and volume of the space.
- A minimum of 231m^2 (aerodynamic free area) of smoke extract ventilation was determined to be needed in the roof of the space at this early stage based on some preliminary assessments.
- A 15m drop automatic smoke curtain was required across the Hall to form 2 high level smoke reservoirs within the Football Hall.
- The smoke vents within the roof of the Hall should be distributed so that 40% were located to the south of the curtain and 60% to the North.

Through discussions with the client it was determined that introducing a smoke curtain at high level within the Football Hall would not be acceptable as it would limit the potential use of the space.

Without the additional of a smoke curtain and given the serrated roof profile within the Football Hall, it was discovered at an early stage that the space would fill quickly with smoke as the profile of the roof encouraged downward flow of smoke. CFD was used therefore to identify the ideal location for inlet and extract vents as well as test a number of differing vent size configurations.

Further detailed CFD simulations were undertaken during the detailed design phase of the project which indicated that the Stage D solution, which relied on the use of an automatic smoke curtain, could be changed and the smoke curtain removed. The smoke control system

would work with an increased area of 248m^2 (aerodynamic free area) for extraction in the roof, combined with an inlet vent area of 226m^2. The inlet vents were positioned on the east side of the Football Hall, with the bottom edge at a height of 3m from the ground. The height of the vents was 2m, with a combined length of 113m. This solution required inlet vents along the entire length of the east wall. The outlet vents were positioned along the edges of the roof rather than distributed equally around the entire roof.

Using this as a basis, further CFD simulations were performed to finalise the quantity of extract and inlet vents required. The bottom edge of the inlet vents was moved to a height of 4.5m from the ground for functional reasons. The height of the vents, and their lengths, were varied over several simulations. Through a process of iteration, an optimal solution was obtained when the vents had a height of 1.5m and a combined length of 103m. This achieved the acceptance criteria of a maintained clear layer height in the space at 4.5m for a duration of 20 minutes. Other simulations that were tried either met the acceptance criteria but had increased inlet areas, or exhibited a problem where the smoke layer descended below 2.5m for a short period within localised areas of the hall. This was deemed to be unacceptable and therefore rejected as a potential solution.

The successful and final installed solution required an inlet vent area of 154.5m^2 (aerodynamic free area) and a high level extraction vent area of 192m^2 (aerodynamic free area).

Figure 7. Location of Smoke vents in Football Hall Roof

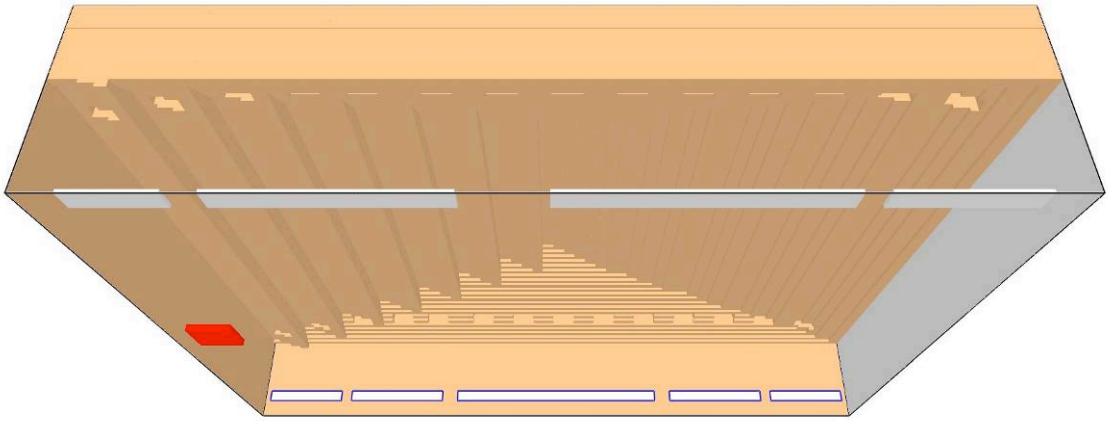


Figure 6. View in Football Hall

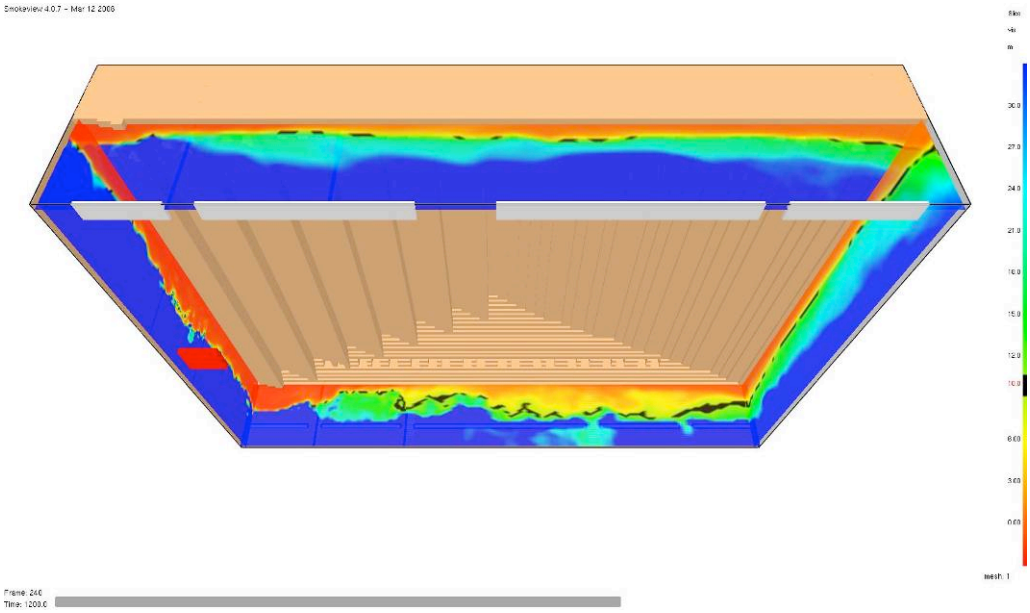


Figure 7. Estimated Visibility in Football Hall at 1200 Seconds

Figure 8. View of Inlet and Extract vents to Football Hall

If the Football Hall was only to be used for indoor football, a smoke exhaust system would not have been needed and technical justification could have been based solely on a qualitative fire risk assessment on the basis that the wide - open expansive design would have presented very little fire risk. However, due to the proposed multi-use of the Hall for concerts etc, a more detailed quantitative fire risk assessment was needed to consider likely fire scenarios and a smoke exhaust system designed to ensure that the available safe escape time for occupants was extended. The use of CFD played a very important part in this process as traditional methods of smoke control design were beyond their field of applicability for this project.

Smoke extract is provided within the Football Hall:-

- To justify the extended compartment size proposed;
- To maintain safe conditions during an evacuation of the Football Hall (5000 occupants potentially);
- To prevent the entire hall from filling with smoke;
- To ensure that fire fighters can safely approach and enter the space in the event of a fire; and
- To justify the multi-use of the hall as a venue for football, concerts, dinner dances, and sporting events.

2.2 FIRE STRATEGY CONCEPT FOR OTHER AREAS WITHIN THE BUILDING

The principles underlying the recommendations of the NDTH for means of escape are that a fire is assumed to grow, spread achieve flashover and consume an entire compartment containing many different rooms and escape routes. This means measures require to be put in place to minimise the time occupants spend in unprotected parts of escape routes. The fundamental concept underlying the fire and escape strategy for Ravenscraig on the other hand, is that a fire will be contained in the room, or area of origin and hence prevent the products of combustion from spreading into escape routes. This is a greater standard of safety than required by the NDTH, where it is assumed that the products of a fire can quickly flow into adjoining areas. Provision of sprinklers in the central spine building and the other construction fire safety/ escape features in place ensures that this is achieved. Many of the underlying objectives of the recommendation of the clauses within the NDTH with respect to means of escape where therefore not directly applicable to this design, so a performance based approach to the design was adopted.

The escape strategy derived for Ravenscraig is bespoke and does not strictly follow many of the traditional guidelines stated within the Non Domestic Technical Handbook (NDTH) [(2)]. The escape strategy was derived based on a risk assessment and fulfils all of the functional requirements of means of escape stated within the Building Regulations. The fundamental principle being that once an occupant leaves the room / area of fire origin, they are provided with a safe means of egress.

In order to be able to do this the fundamental principles of means of escape prescribed in the Building Regulations and the underlying assumptions that this is based on, had to be identified and clearly understood. This is covered in 4.2.1.

In fire engineering terms, this means that occupants should be provided with the opportunity to escape before conditions become untenable due to fire. This is often termed as an assessment and comparison of the available safe escape time (ASET) with the required safe escape time for occupants (RSET). As long as the RSET is less than the ASET then an acceptable condition and safe outcome will be achieved. This is outlined within BS 7974-6:2004 [(3)].

In the case of Ravenscraig, escape provisions were configured to provide all building users with adequate means of escape from fire. All occupants are afforded the opportunity to reach a place of safety, or protected zone within an acceptable travel time. Alternative directions of escape and the ability to turn and move away from a fire are provided in the majority of locations within the buildings. Where a single means of escape exists, suitable measures are installed to guarantee the safety of the occupants in these locations.

Active and passive fire safety systems are provided and combined to ensure that the escape routes are protected in a sufficient manner from the effects of fire.

3.0 RAVENSCRAIG SPRINKLER SYSTEM DESIGN

The sprinkler system provided for the Ravenscraig Sports Facility meets the guidance offered in the NDTH in that ‘the level of fire suppression is appropriate to the occupancies within the building and this was determined on the basis of a risk assessment’

1. The sprinklers are installed to prevent fire spread between the spine part of the building (Compartments 3, 4, 5 & 7) with the intention of containing a fire within the room of origin
2. The sprinkler system is designed as a life safety fire suppression system
3. The system is categorised in accordance with BS EN 12845 in agreement with the regulatory authorities. OHI & OHIII
4. The water supply tanks are provided by fully hydraulically calculated tanks with 60minute period of duration for sprinkler coverage
5. Quick response sprinkler heads are used throughout to ensure the earliest activation
6. The system comprises of separate zones for each floor with monitored valves (or valves in secured locations)
7. All sprinkler heads have an operating temperature of 68oC.
8. The system was installed by a reputable LPC approved specialist sprinkler contractor and the sprinkler installation, in all aspects, was designed and installed in accordance with BS:EN:12845.

4.0 RELAXATIONS FOR DEPARTURES FROM THE RECOMMENDATIONS OF THE NDTH

Relaxations for the departures from the recommendations of the NDTH were sought for in respect of:-

1. Football Hall compartment area
2. Open stairs used for escape
3. Fire and smoke control doors in the first floor corridor
4. Extended travel distances in Football Hall, Athletics Hall Strength Training room, and toilets serving the Medical Area within the Link building
5. Destination of escape from toilets serving Link first floor Medical Area
6. Use of the Football Hall Gallery as a means of escape from the Sports Hall Gallery.

Each of the items of departure were agreed with North Lanarkshire Building Standards and Strathclyde Fire and Rescue.

4.1 BUILDING FORMAT

Departure from Clause 2.9.6 – Destination of Escape from Toilets serving Link First Floor Medical Area

In some cases within the Link building, escape routes are configured such that the destination of escape arrangements as stated by clause 2.9.6, do not meet with the prescriptive recommendations e.g.:-

- The toilet which serves the Medical area on the first floor
- Staff changing areas
- Scottish Athletics office
- SFA office
- Events managers office
- Operations managers office
- NL football development office

All of the above would be deemed to be non-compliant with the Technical Standard.

The NDTH recommend that an escape route should give access to a place of safety or to another compartment (see clause 2.9.4):
a) directly; or
b) by way of a protected zone or unprotected zone; or
c) by way of an unprotected zone to a protected zone; or
d) by way of a flat roof or access deck (see clause 2.9.17); or
e) by way of an exit to an external escape stair (see clause 2.9.24); or
f) by way of one other room with the escape route from that other room should be in accordance with the guidance in a, b, c, d or e above
The intention of this functional requirement is to ensure that in the event of a fire and building evacuation, the number of rooms that occupants have to pass through is limited.

4.1.1 GROUNDS FOR DEPARTURE

Most of the rooms referred within this area i.e. Rooms 16. (Scottish Athletics Office), 18. (Scottish Football Association Office), 20. Events Managers' Office), 21. (Operations Managers' Office) & 22. (North Lanarkshire Football Development Office) are accessed off Room 23. (Reception/ Open Plan Office). Should a fire occur within Room 23., occupants will be able to escape safely via the Staff Kitchen. As previously mentioned, the escape strategy (designed to justify having 'open stairs'), is based on containing a fire incident within the 'room of fire origin'.
Although some of the rooms are entered off the Staff Kitchen, the Staff Kitchen (Room 15) will not be used for cooking purposes and will only contain domestic type appliances e.g. a microwave, a toaster and kettle. There is no gas supply and the room does not present a high fire risk. The three rooms referred to are 11. (Male Change) 12. (Female Change) and 13. (Break-out-space). As there are two means of escape available from the Staff Kitchen, occupants will be able to turn and move away from any fire incident occurring within Room 14. (Maintenance & Grounds).

4.2 OPEN STAIRS USED FOR ESCAPE

NDTH recommends that '*an escape stair should be within a protected zone'.*

One of the main features of the fire strategy at Ravenscraig Sports Facility is to contain a fire within the 'room of fire origin'. This is achieved by enclosing rooms off the stairs in fire rated or smoke retardant construction. Following consultation with the regulatory authorities, the provision of FR60 construction was introduced to the design (enclosing construction at ground floor level). As ground floor walls are predominantly comprise of blockwork, this was achieved without compromise to the original construction or design.

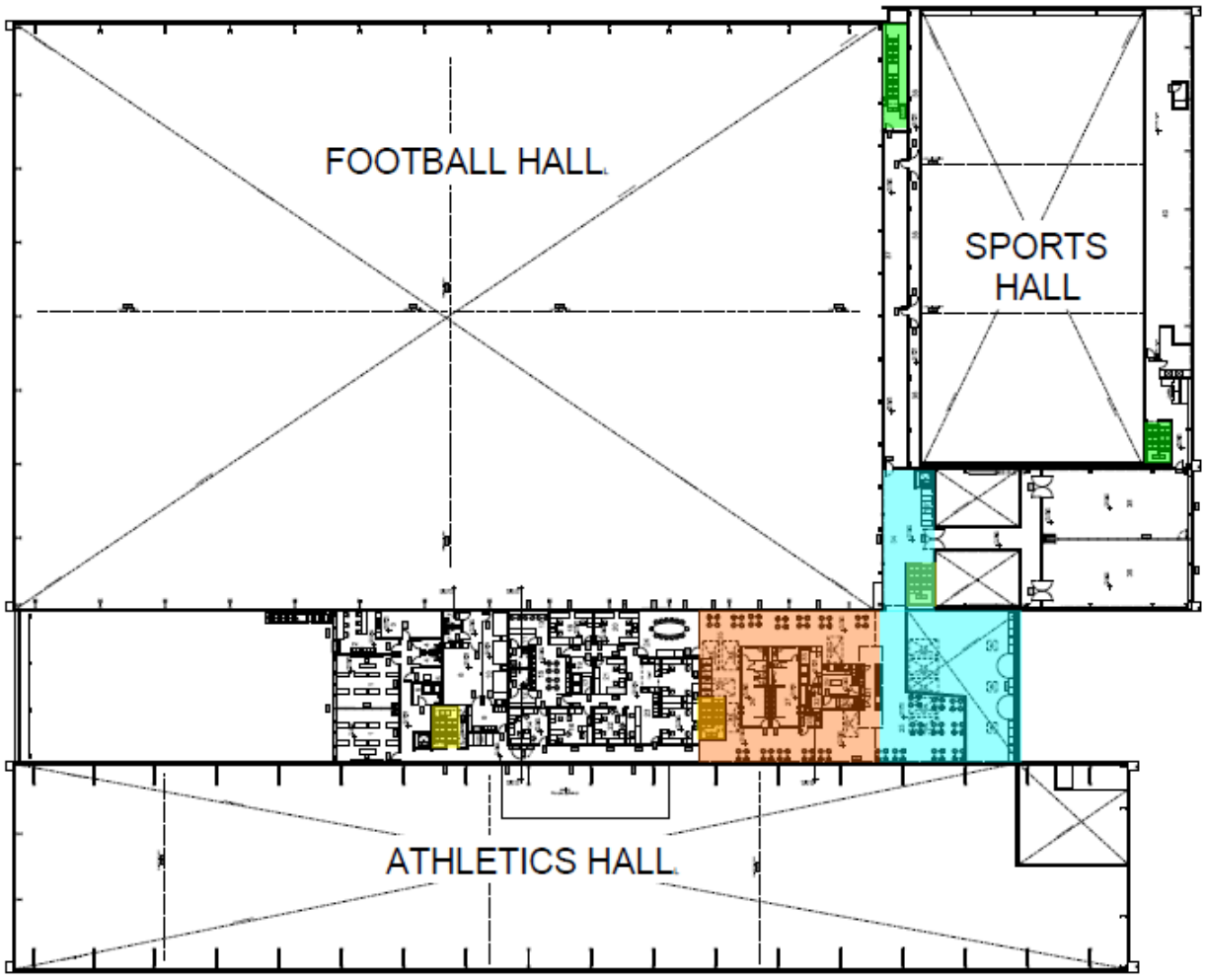


Figure 7. Escape Stairs

4.2.1 TRADITIONAL METHODOLOGY FOR MEANS OF ESCAPE DESIGN

The NDTH recommends a number of control measures for means of escape design within new buildings.

These include amongst others:-

1. Provision of adequate numbers of escape routes based on occupancy, height and travel distance.
2. Limiting travel distance, as a means of limiting the time occupants can potentially be exposed to the affects of fire and, also in the theory, that occupants must be evacuated in under 2.5 minutes.
3. Provision of alternative and independent escape routes to ensure occupants do not become trapped by fire and also ensure that should one exit become compromised an alternative exit is available.
4. Limiting the number of rooms that must be passed through to reach an escape route, to simplify escape routes and aid awareness in the routes that should be taken. This is also so that occupants do not inadvertently escape into the room of fire origin.
5. Ensuring escape routes are not obstructed.

6. Ensuring escape routes are wide enough to ensure a sufficient flow of people to such that escape is not hindered. The assumption being that occupants escape quicker in wider escape routes.
7. Ensuring corridors are separated by smoke control provisions such that if one exit becomes blocked, there is always a second alternative route available.
8. Ensuring that escape does not come too close to the edge of openings in floors to prevent flames and smoke from a fire below preventing or affecting escape.
9. Enclosing all stairs used for escape purposes within fire resisting construction and ensuring that these stairs discharge to a place of safety outside the building.
10. Provision of protected lobbies to escape stairs to ensure that the likelihood of smoke from a fire compromising an escape stair is minimised.
11. Provision of compartmentation in a building provides a safe refuge for occupants as well as preventing fire and smoke spreading between differing areas.
12. Temporary waiting spaces provided within safe area are acceptable as a means of disabled evacuation and intervention and assistance by building management is essential to ensure the safe evacuation of people with disabilities.
13. The principle of progressive horizontal evacuation is acceptable as an alternative to providing waiting spaces in escape stairs.
14. Suitable escape and emergency lighting is required guide people to escape routes in the event of failure of the general lighting.
15. Automatic fire detection is not required as a life safety feature in an assembly building.

These control measures are based on the following underlying assumptions that are made within the NDTH:-

- No active fire safety or control systems are needed, or are present within a building e.g. smoke control, automatic detection, sprinklers. There is a reliance on the need to provide passive (physical) construction to protect people.
- Once a fire ignition takes place, it grows quickly before occupants become aware of it, hence reducing their available safe escape time.
- There will be a delay in a fire being detected and warning be raised and the evacuation process being initiated.
- Some degree of fire and smoke spread will take place beyond the room of fire origin. The assumption is that once out of the room of origin an entire compartment and its escape routes can be involved/ affected.
- One escape route, or stair will become compromised, or blocked because of fire, or smoke and as such an alternative route must always be provided.
- Travel distance needs to be limited to reduce occupants' exposure time to the products of combustion and reduce their escape time.
- It is acceptable in some circumstances for occupants to escape via non enclosed stairs where the risk is deemed to be low enough.

These assumptions are not appropriate to make in every building as in the case of Ravenscraig, where active and passive fire safety systems are provided and combined to ensure the escape routes are protected in a sufficient manner from the effects of fire.

4.2.2 ESCAPE STAIRS DESIGN AT RAVENSCRAIG

Five stairs are provided to the first floor as a means of vertical escape, shown in the Figure 7.

Two escape stairs (Stairs 5 & 6) are enclosed in fire resisting construction and discharge directly to a place of safety outside the building.

Three unenclosed stairs (Stairs 1, 2 & 3) are provided. These are available for use in the event of a fire, or an emergency. None of these stairs discharge directly to a place of safety outside at ground level. Instead, they discharge to a protected corridor at ground level which in turn discharges either to outside, or an alternative fire compartment.

To ensure that the proposed vertical means of escape is viable and safe, the threat of a fire occurring at ground, or first floor level has been considered.

A fire at ground floor level within the accommodation cannot affect the unenclosed stairs leading from the first floor, due to the provision of the protected corridor and alternate directions of escape at ground level.

Essentially, the base of the unenclosed stairs is within a 'relative protected zone' and will be provided with alternate escape routes that lead to exits. Provision of fire resisting and smoke retarding construction between the accommodation and stairs concerned shall prevent a fire, or its products on the ground floor rising through the voids containing the stairs from the first floor.

The area around the base of the unenclosed stairs within the Link Block will form an area of limited fire potential with limited / controlled combustibles present. Vending machines will be separated from the stair enclosure with automatic fire curtains. In the case of the Interaction Zone this whole area is separated from the corridor with a fire curtain.

At first floor level, all three stairs will be open to the accommodation. To ensure that this does not pose a hazard for escape the following measures have been provided:-

- A fire occurring within a room will be contained within this room by the room enclosure.
- A fire will also be prevented from spreading beyond the room or area of origin by the sprinkler system proposed.
- The smoke extraction and containment system within the Entrance Foyer and Café shall ensure that smoke is contained above one area of the first floor and extracted such that a clear layer is maintained above the escape routes in this area.

These measures ensure that the unenclosed stairs are not compromised by a fire at first floor level, or in the worst case only a single stair is affected. This meets the functional requirements of the building regulations. The width of each escape stair was based on the assumption that one stair could be compromised by a fire, even although this is an unlikely event given the protection measures in place.

5.0 CONCLUSIONS

The fire safety strategy for Ravenscraig was developed with the intention of complying with the Building (Scotland) Regulations 2004 [(1)]. Although, the bespoke nature of the sports facility design did not strictly follow some aspects of the prescriptive guidance outlined within the Non Domestic Technical Handbook [(2)] (NDTH) it was demonstrated that the fire safety precautionary measures introduced into the building would ensure the functional requirements (mandatory standards) outlined within the building regulations were satisfied.

The Ravenscraig Regional Sports Facility has many fire safety precautionary features, both passive and active, e.g.:-

- there is a high degree of compartmentation within the building;
- most rooms are designed to contain a fire incident within the room of fire origin;
- an "L1" fire detection alarm system is installed throughout the complex;
- in addition to voice recorded messages the fire alarm system incorporates a live and directive public address voice alarm warning system;
- an autodial facility has been provided to allow for an early response of the Fire Service;
- trained staff will always be present within the building;
- simultaneous evacuation of all building occupants will come into effect on confirmation of fire;
- a life safety sprinkler system is installed throughout the central spine part of the building;
- a smoke control system has been provided to the main circulation area within the building;
- a smoke control system has been provided within the Football Hall;
- An Emergency Control Room, with the necessary control panels, is being provided for the use of the Fire Service

All these fire precautionary features will assist in ensuring that occupants will evacuate the building safely and circulation routes and entry points into the building will be provided with a relatively smoke free environment for the Fire Service to carry out their operational duties.

6.0 REFERENCES

[1] Scottish Government (2004). *The Building (Scotland) Regulations 2004.*
[2] Scottish Government (2004). *The Non Domestic Technical Handbook*
[3] British Standards Institution (2004). *BS7974 PD6 Application of fire safety engineering principles to the design of buildings – code of practice Human Factors: Life safety strategies – occupant evacuation, behaviour & condition.*