USING CFD FOR SPORTS ARENA AND STADIA DESIGN

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ABSTRACT

Engineering projects are now demanding design solutions that are beyond standard practise. To meet this challenge the utilisation of sophisticated numerical modelling techniques, such as Computational Fluid Dynamics (CFD), are inexpensive yet effective tools in being able to provide innovative engineering design solutions.

Occupancy issues in newly developed sports arena complexes and stadia are increasingly becoming paramount, for reasons associated with occupant comfort, health and safety as well as sustainable development in terms of capital cost and energy consumption.

This paper will present the use of the PHOENICS CFD code in the engineering design development process of several large sports stadia and sporting arena complexes. Various design issues relating to occupancy comfort, fire safety, exhaust discharge and stadium pitch and stand (bowl) ventilation will be presented and discussed.

By using CFD in this manner it is anticipated that these types of advanced performance-based studies can be used as a benchmark for similar projects worldwide and be promoted as world's "best practise" in sports arena and stadia design.

INTRODUCTION

Occupancy issues in newly developed sports stadia and leisure complexes are increasingly becoming paramount, for reasons associated with occupant comfort, health and safety as well as sustainable development in terms of capital cost and energy consumption. It is increasingly becoming common to use Computational Fluid Dynamics (CFD) techniques as a cost effective and innovative method to assist in the engineering design process to achieve the desired outcomes.

By using CFD at an early stage of the engineering design process, many numbers of investigations can be conducted. These can relate to the natural or mechanical (HVAC) ventilation of the arena or complex relating to spectator comfort aspects, the threat to life safety due to fire and smoke spread and specialised assessment of topics (eg: pitch ventilation) unique to sports complexes.

In regards to stadia, most patrons will come as spectators to sit in the stadium bowl to watch and enjoy an event on the pitch. The needs and comfort of these people as the "building occupants" have to be addressed just as stringently as those who use internal areas such as restaurants and function areas.

Occupant comfort in these types of naturally ventilated environments is affected by the air temperature, the air movement and solar radiation. The air temperature in the bowl is mainly dependent on ambient conditions but is also affected by direct solar radiation warming building elements including the roof. The extent of natural ventilation also affects the air temperatures, as greater air exchange will reduce the effect of localised heat sources such as body heat as well as the effect of the solar radiation. If the natural ventilation is reduced, say by closing the roof for stadiums with retractable roofs, this will reduce the air movement with the bowl arena which can adversely affect overall spectator comfort on days of high ambient temperatures.

The following section provides a list of case studies of using the PHOENICS CFD code for assessing the natural ventilation within various stadia as well as mechanical ventilation within enclosed sporting arenas.

CASE STUDIES

Telstra Dome – Melbourne, Victoria

This recently built 52,000-seat stadium (formerly known as Colonial Stadium) located within the Melbourne Docklands redevelopment precinct represents the latest generation of high quality sports and entertainment facilities. It incorporates a 167m by 132m retractable roof, for both spectators and the pitch, that provides a fully enclosed all weather facility. When the retractable roof closes, the stadium bowl arena becomes arguably the largest "public building" in Australia, and the comfort conditions of the occupants needs careful consideration.

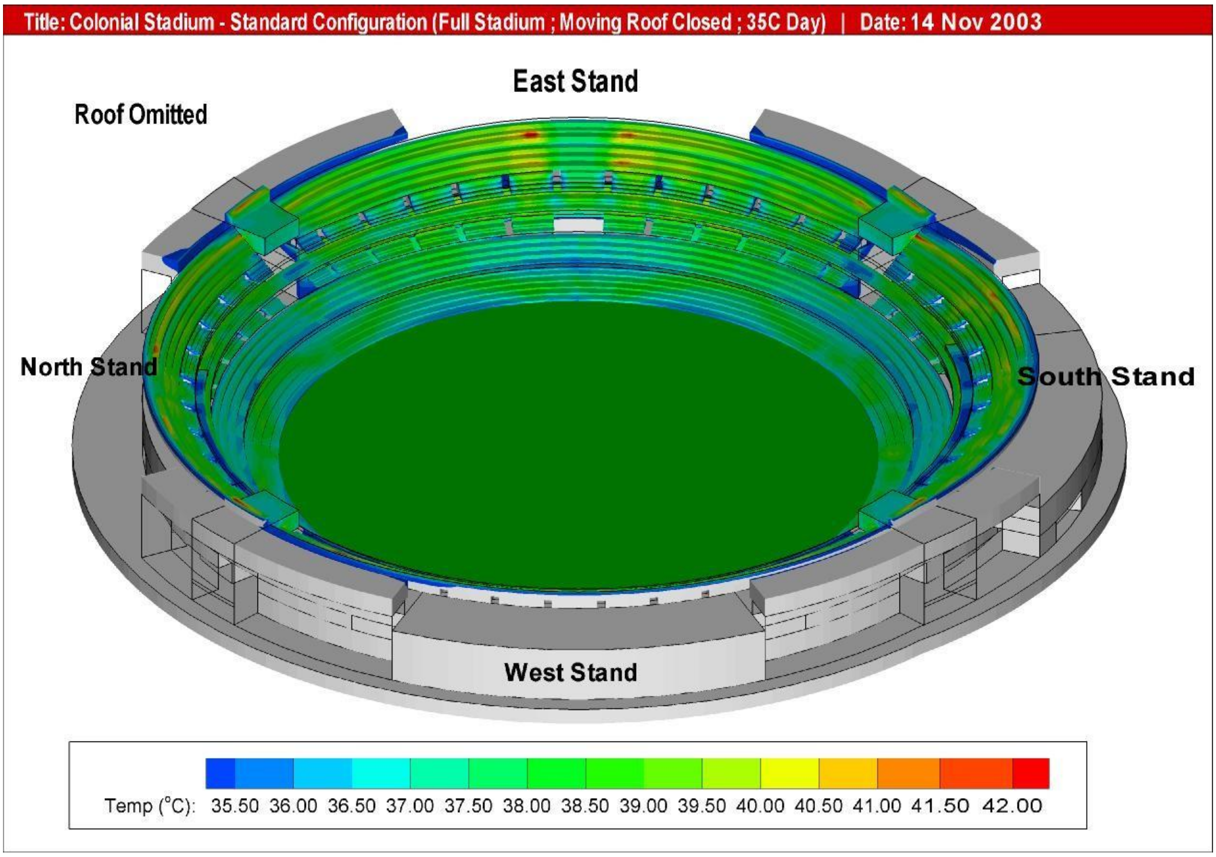
Due to the concerns of the capital cost and ongoing energy impost of using a large mechanical ventilation system, CFD was used to demonstrate an effective natural ventilation solution for the bowl and adjacent areas appropriate for the various operating modes of the stadium.

The aim of the CFD studies conducted was to optimise the design from a capital cost perspective and to address architectural concerns regarding possible drafts and wind driven rain as well as noise break-out issues. The modelling analysis included the effects of people (via heat gains) and the solar loads.

The preliminary analysis indicated the importance of adequate natural ventilation openings at high and low level as well as suitable roof insulation in being critical to occupant comfort within the stadium. Based upon these considerations, strip roof-vents, a vertical space between the fixed roof and retractable roof (when in the fully closed position) and suitable façade and vomitory openings were incorporated into the stadium design.

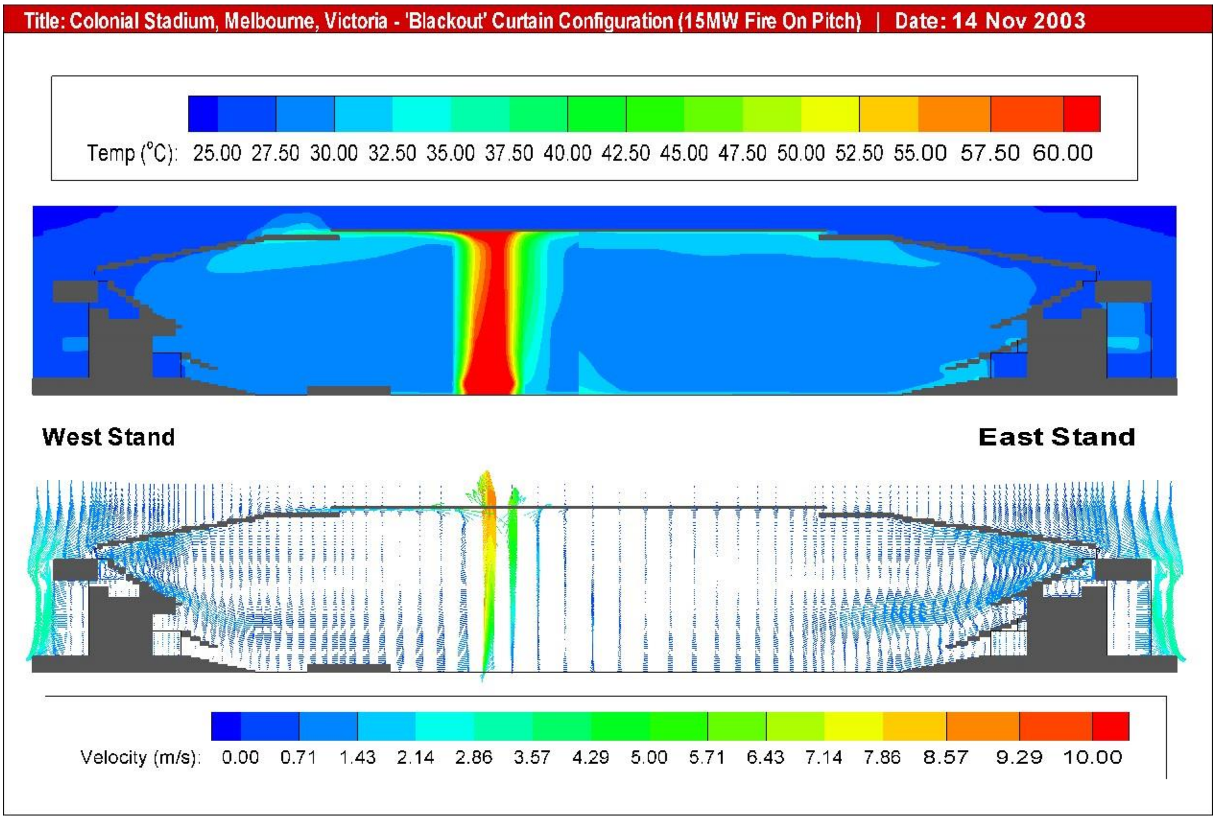
Optimisation studies included three different roof vent configurations and spacings as well as several variations to the facade opening restrictions. To ensure a robust solution, an onerous design case was used as the basis of the studies, namely that spectators are located throughout all sections of the stadium for a major concert or similar on a hot, still (no external wind), sunny day with the roof closed.

As well as the nominated design case, the effect of different ambient and occupancy conditions were also investigated as part of a sensitivity study. In addition, concert configuration 'black-out curtain' analyses were performed to establish that adequate comfort, in the stand and on the pitch, was still maintained even when significant "light-lock" restrictions were placed in front of the vomitories and other 'back of house' openings.



By undertaking a detailed study of passive engineering techniques for ventilating the bowl and adjacent public concourse areas, an optimised solution was developed that was designed to keep temperatures within 5°C of ambient during summer, to reduce drafts and wind driven rain during winter and which were still maintained under the design criteria for lighting "black-out" and acoustic "noise break-out" specifications for concert events.

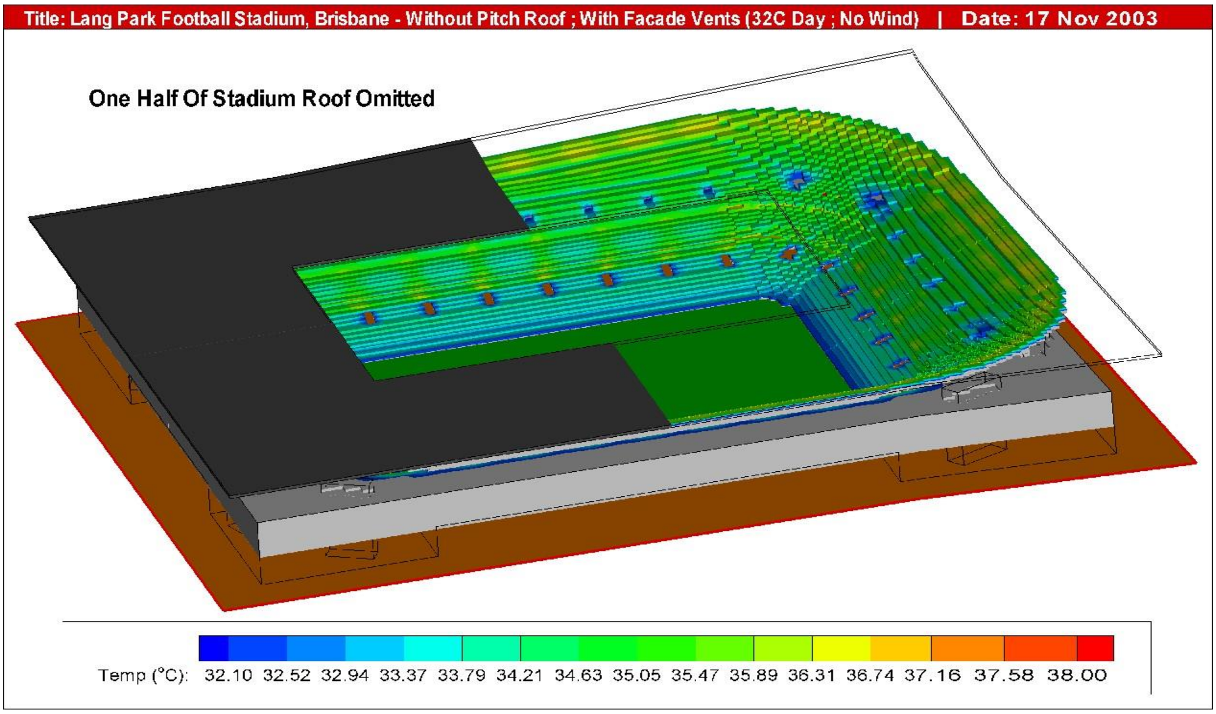
In addition to the natural ventilation and thermal comfort analyses, fire safety issues were also considered as part of the design process, specifically for the situation with the pitch roof closed. The fire scenarios considered were up to sizes of 15MW output, which was deemed to represent typical conditions of burning concert equipment (eg: speaker racks).



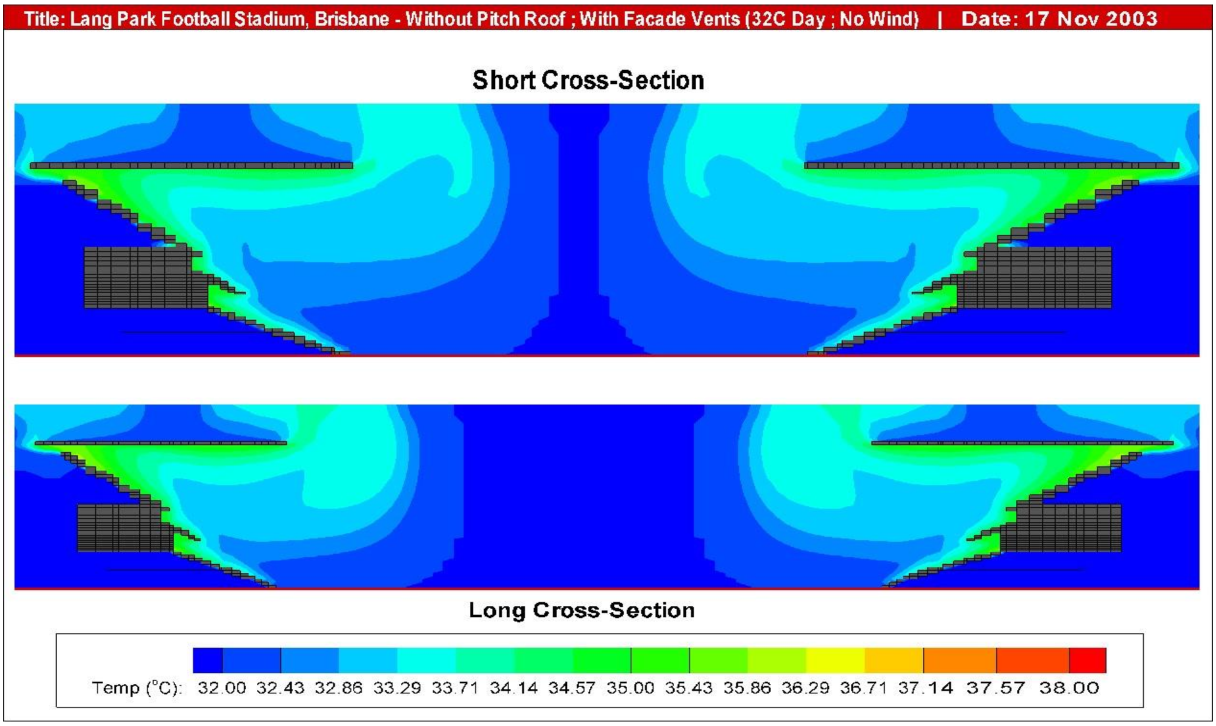
The analysis showed that in spite of the pitch roof being closed the majority of the hot gases and smoke is adequately vented through the gaps between the retractable roof and stands. Assuming patrons are moved or evacuated to a distance of 40-50m away from the fire source, it was demonstrated that tenability criterion in terms of temperature and toxicity (smoke) would be satisfied for all spectator occupied areas of the stadium bowl.

Lang Park Stadium – Brisbane, Queensland

The Lang Park football stadium was recently redeveloped for increased capacity. As it is being designed to be capable in the future of incorporating a retractable pitch roof, CFD modelling was conducted to determine the natural ventilation openings necessary to provide acceptable spectator comfort conditions. Several scenarios were simulated for different environmental conditions in the case of both an open stadium and with a pitch roof.

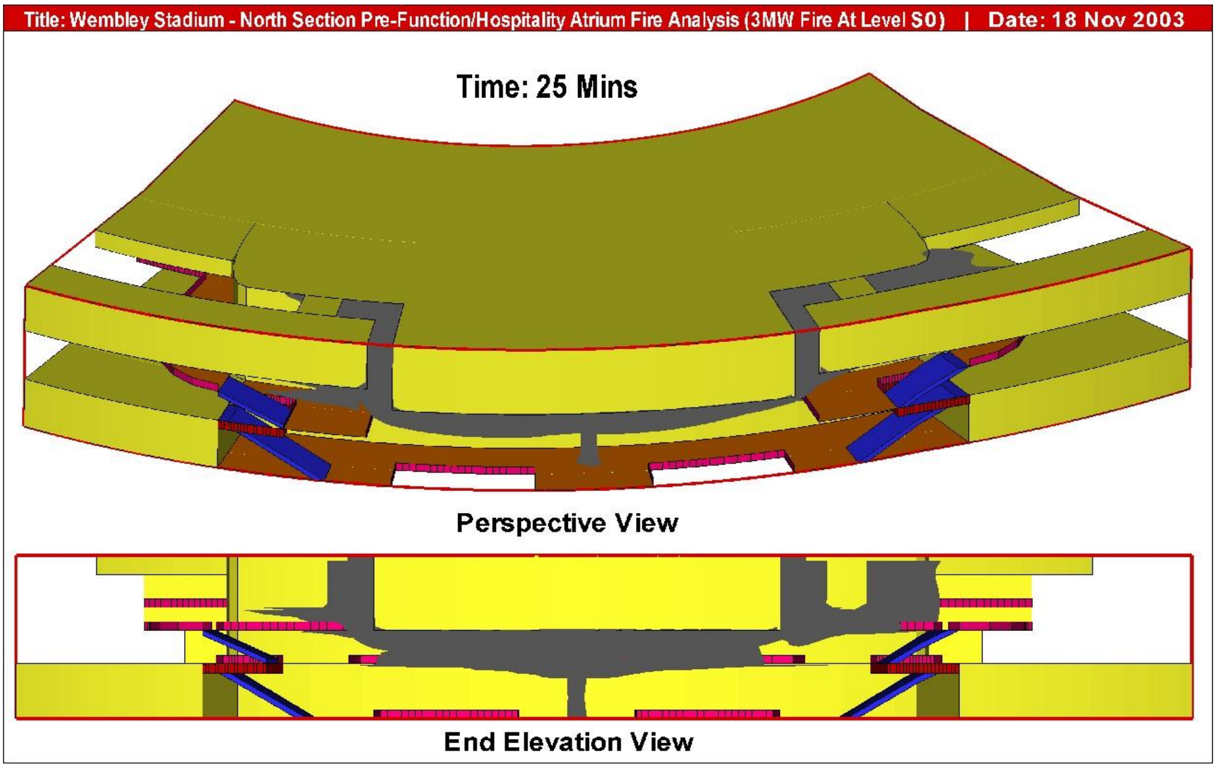


Based upon previous experience obtained with the Colonial Stadium (Telstra Dome) design study high level perimeter vents were located in the vertical façade wall at the rear of the back row of seating of the upper tier, which was sufficient to keep temperatures within 4°C of ambient.



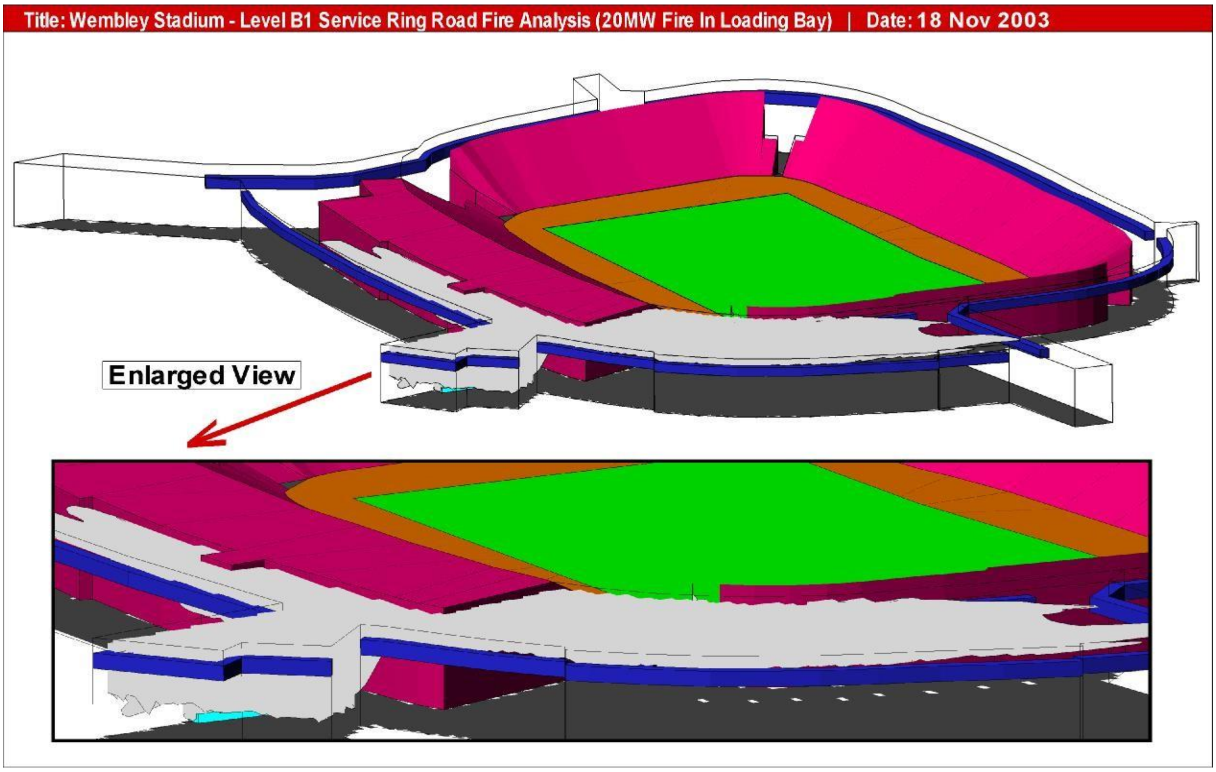
Wembley Stadium – London, UK

This international sporting icon is in the course of being redeveloped so as to uphold the unrivalled status of this unique venue well into the twenty-first century. As part of this process a comprehensive fire engineering design review is required to address issues associated with the Building Regulation compliance as well as confirming conformance with the United Kingdom Green Guide principles for sports stadia.



In support of the fire engineering review, substantial CFD modelling is being undertaken to demonstrate compliance with performance requirements in respect to extended tenability being achieved in nominated areas of the stadium. A key feature, in far as feasible, is the avoidance or limitation of mechanical smoke management systems in the stadium concourse areas in favour of passive (architectural) measures, as this approach provides the greatest reliability as well as lowest cost.

An unusual feature of this stadium is that it incorporates an underground service "ring road" below the stadium pitch arena, primarily for access and parking facilities for service and outside broadcast (OB) vehicles. As such, this area is effectively similar to a road tunnel and an effective mechanical smoke extraction system needs to be designed to meet regulatory requirements.



Design fires up to 35MW were considered. The fire is assumed to occur within an OB vehicle or similar truck. The fire scenarios are conservatively modelled as steady-state conditions, because it is assumed that this condition will occur by the time it will take for the Fire Brigade personnel to respond and physically arrive at the scene (typically around 15-20 minutes after fire initiation).

Various case scenarios were considered, including different fire locations and sizes, different mechanical extraction rates and with and without the influence of a sprinkler system activated. For the sprinkler activated cases the fire is assumed to be shielded by the roof of the truck and the fire plume is only exhausted from the top rear of the truck. For the calculations representing the non-activation of the sprinkler system (viz. sprinkler failure) the fire is assumed unshielded with the entire truck on fire.

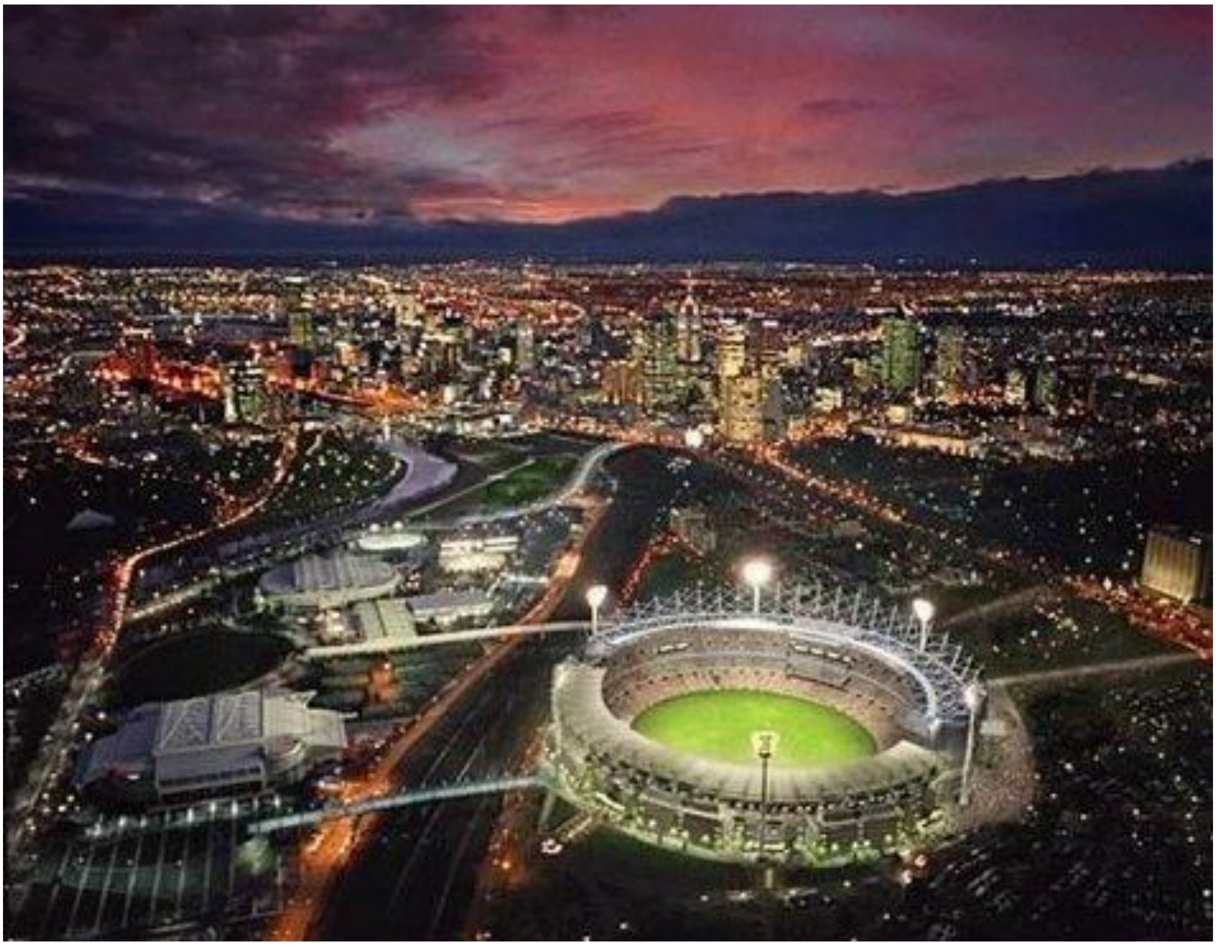
The results from the CFD analysis were used to ensure the mechanical extraction system satisfied the criteria of indefinite tenability beyond 60m either side of the fire location and below a vertical height of 2m for temperature (heat/radiation) and smoke (visibility/toxicity).

MCG Redevelopment – Melbourne, Victoria

The world renowned Melbourne Cricket Ground (MCG) is currently being redeveloped with the old Ponsford Stand, Members Pavilion and Olympic Stand being replaced by the new Northern Stand. This project is set to transform this historic stadium into Australia's prominent sporting facility and reaffirm its position as one of the world's greatest sporting icons. It will also provide the MCG for the very first time the opportunity to showcase and display under one roof the memorabilia and sporting events unique to Australia, such as Australian Rules Football, Cricket, Olympics and Sport Australia Hall of Fame.

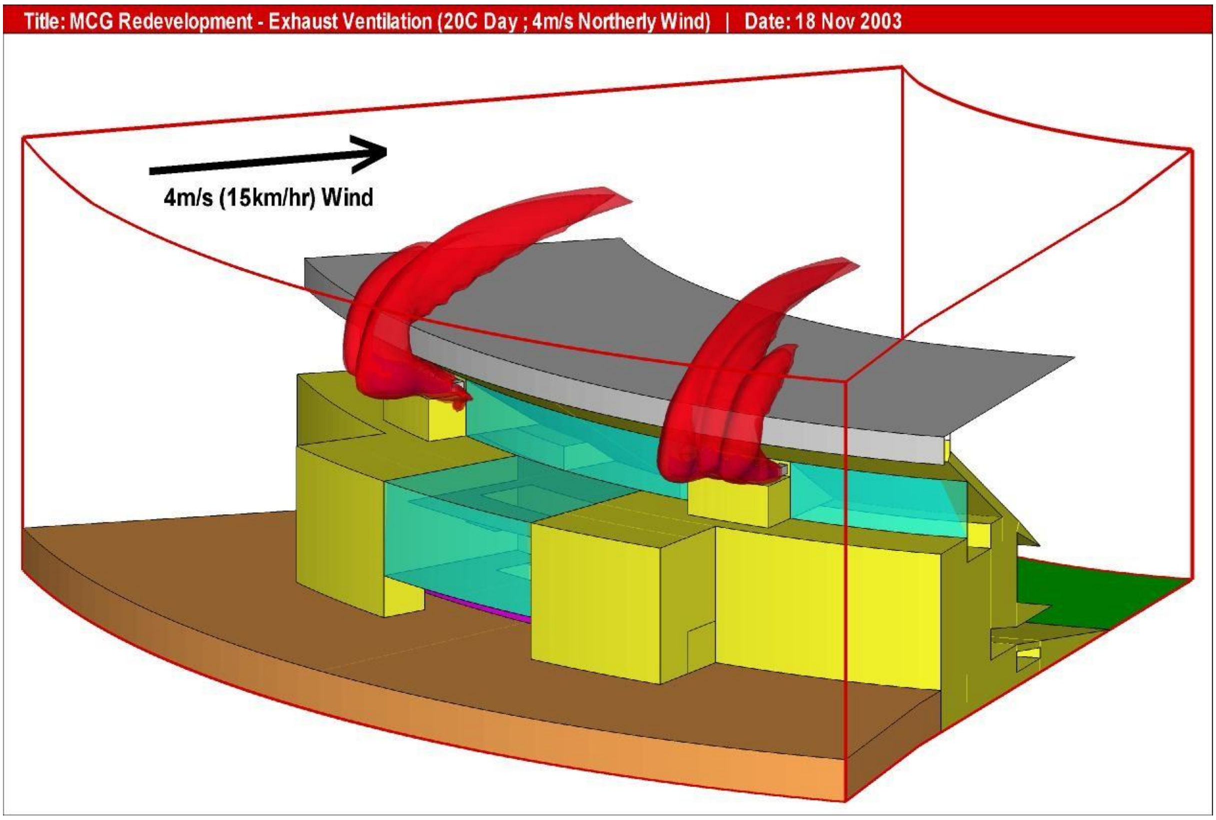
A key objective of the project is that the redeveloped MCG will reflect community aspirations in relation to sustainable environmental and ecological initiatives, with a multitude of measures ensuring that the stadium meets and exceeds social and regulatory expectations. The onus for the engineering design is to reduce the demand for energy, utilise building systems for optimum operational and resource efficiency and incorporate innovative and environmentally sustainable initiatives into the redevelopment where feasible.

As part of this design process advanced engineering modelling analysis has been utilised to optimise the use of natural or passive features of the building structure such as orientation, ventilation and solar shading. Ventilation is a crucial factor in the design of the new building and in order to understand this important aspect, the use of Computational Fluid Dynamics (CFD) techniques have been used. Several key ventilation studies have been conducted.



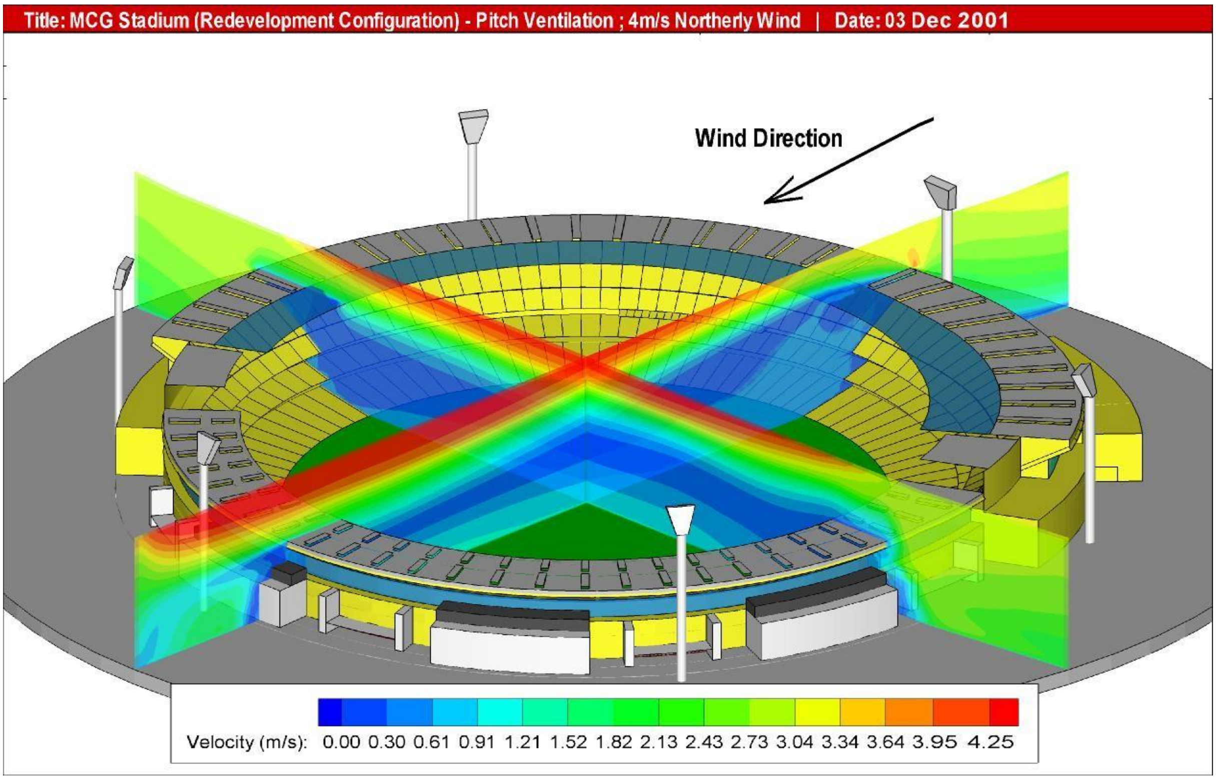
Modelling was performed for assessing the thermal comfort for spectators seated within the new Northern stand region of the bowl arena. Different environmental scenarios were considered and an optimisation of the position and sizes of the high level openings and roof vents was performed. In addition, the general air movement and patterns within the internal areas of the stand and stadium bowl was also investigated.

The examination of the exhaust dispersion from the high level plant rooms discharge was conducted for different wind conditions to confirm that the operational design of the vent discharge was sufficient to ensure that the exhaust did not impinge upon or migrate towards occupied areas of the stadium. A similar study was carried out for the natural ventilation of the exhaust plume from the central plant-room air chillers located within the basement area of the outer concourse region of the stadium.

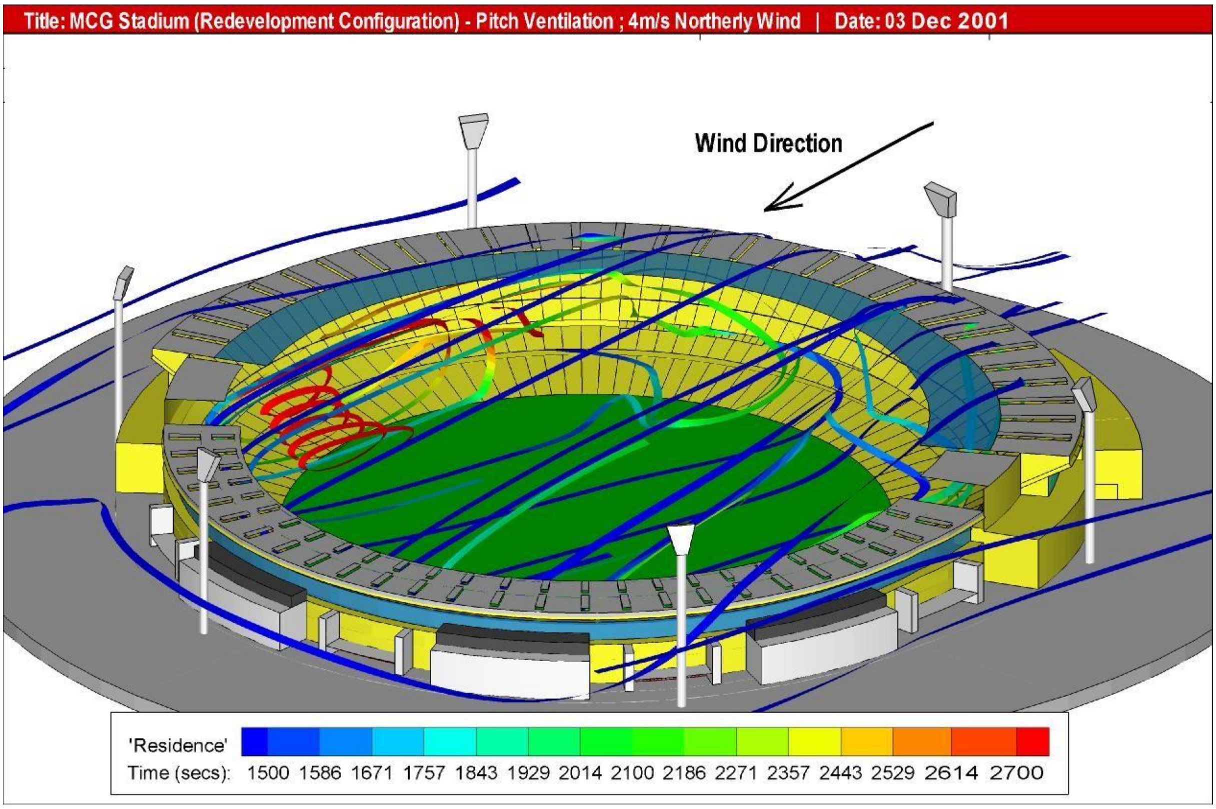


In addition, as concerns were raised due to the construction of the new Northern Stand in reference to pitch health issues, an investigation to evaluate the relative changes in the air movement patterns across the pitch was also performed. Thus a comparison of the wind movement for the both the existing and new stadium development was conducted.

This study showed that the stadium stands obstruction causes a flow recirculation within the bowl arena, just above the pitch surface level, which produces flow in the opposite direction to the wind. The flow pattern and magnitude of the pitch velocities are for the most part influenced by the size and shape of the stand obstruction on the windward side of the stadium. The downstream side is of a lesser secondary influence. The average pitch velocities for the new redevelopment stadium configuration are in general higher than those observed for the existing stadium. This is particularly the case when the winds are form a northerly or westerly directions as the new Northern Stand creates a larger obstruction to the oncoming wind.



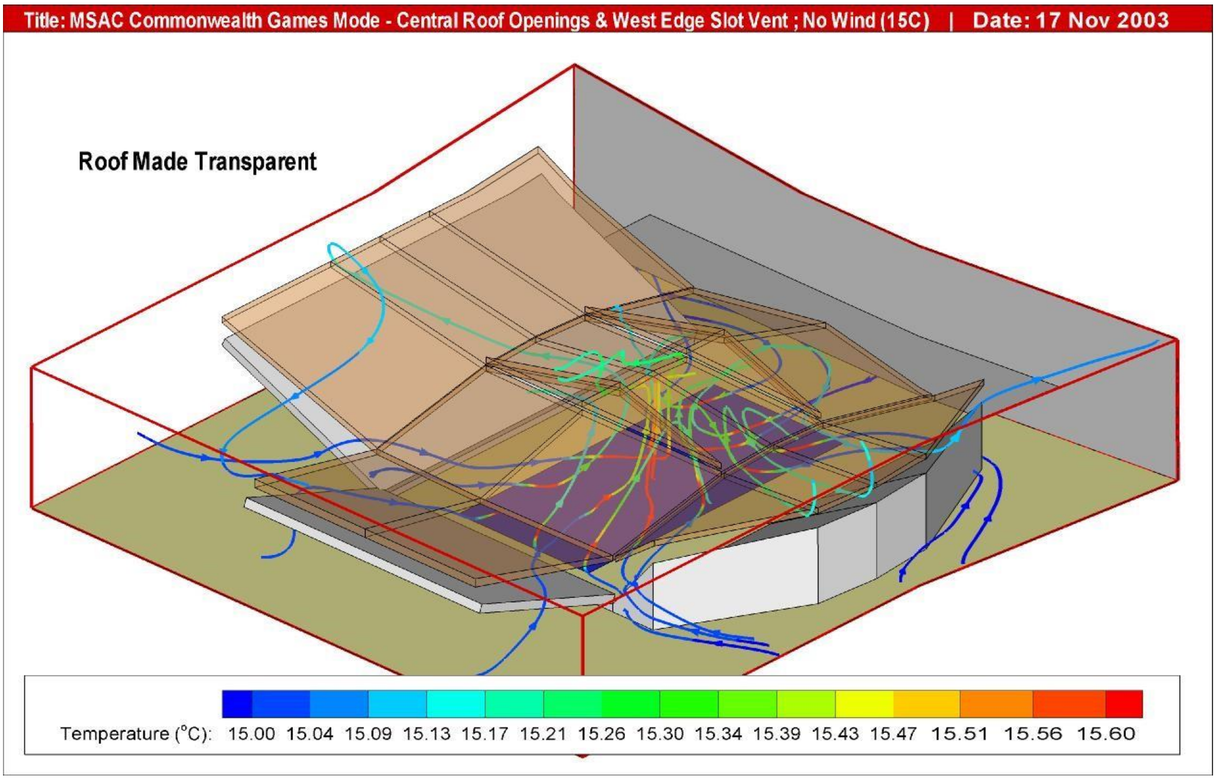
The outcome of this study indicated that significant modifications to the new stadium design to increase the pitch ventilation are unlikely to be necessary, as in general the simulations predicted higher pitch velocities compared to the existing stadium configuration. However, the 'residence' time of the flow around the edges of the pitch tend to be longer for the new stadium, which is a consequence of the stronger recirculation and also implies that the rate of air exchange in these areas is less.



MSAC Extension– Melbourne, Victoria

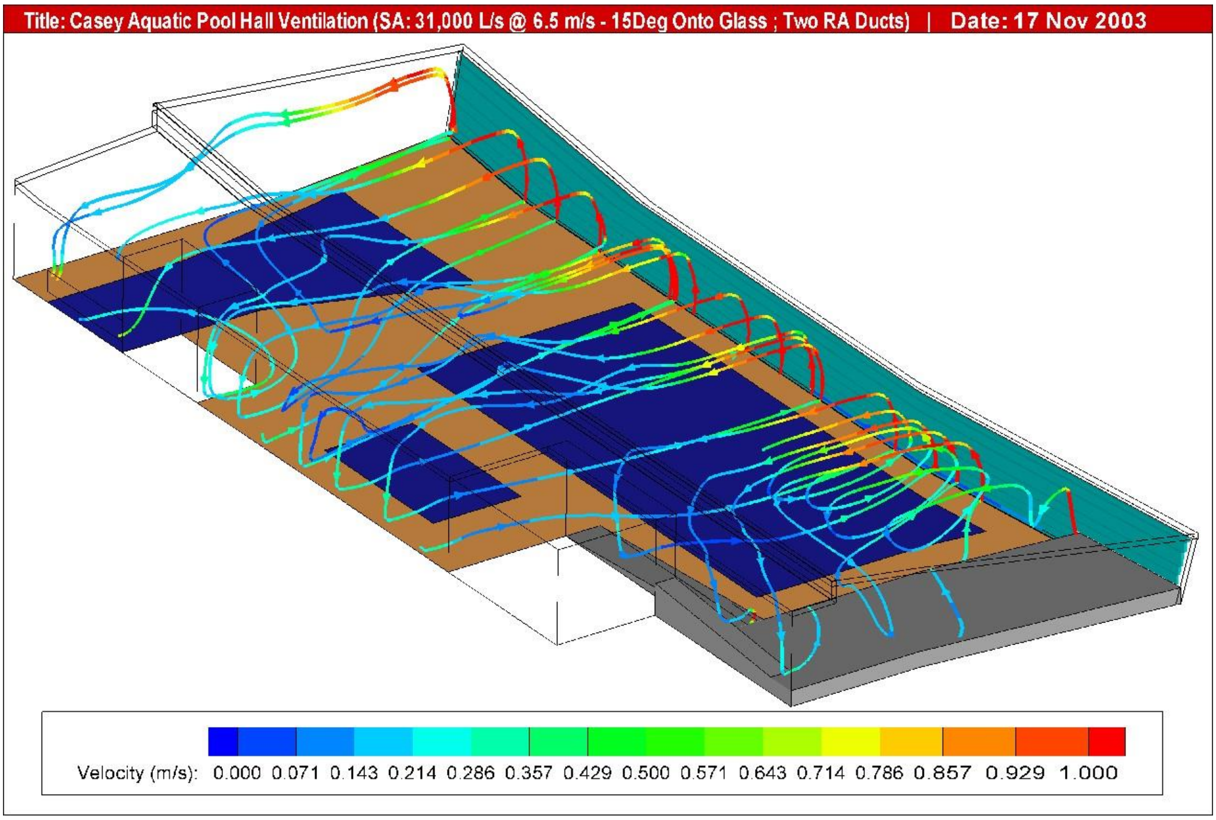
Due to Melbourne hosting the Commonwealth Games in 2006, the facilities at the Melbourne Sports & Aquatic Centre (MSAC) are being currently upgraded. Part of the proposed extensions to this facility includes a new pool arena, which due to its lightweight roof and open sides becomes effectively an outdoor venue. Under these conditions the requirement for cost efficient heating and ventilating the facility poses a considerable challenge particularly in view that the operational requirement of the facility is that it is to be in use all year round.

Whilst most facilities of this type around the world are either mechanically ventilated or air conditioned, for reasons associated with operating costs as well as sustainable development, a passive (natural ventilation) engineering analysis using CFD was undertaken. Comparing the costs of mechanical ventilation systems against supplementary natural ventilation features clearly demonstrated the viability of the final design even without considering ongoing operational and maintenance costs.

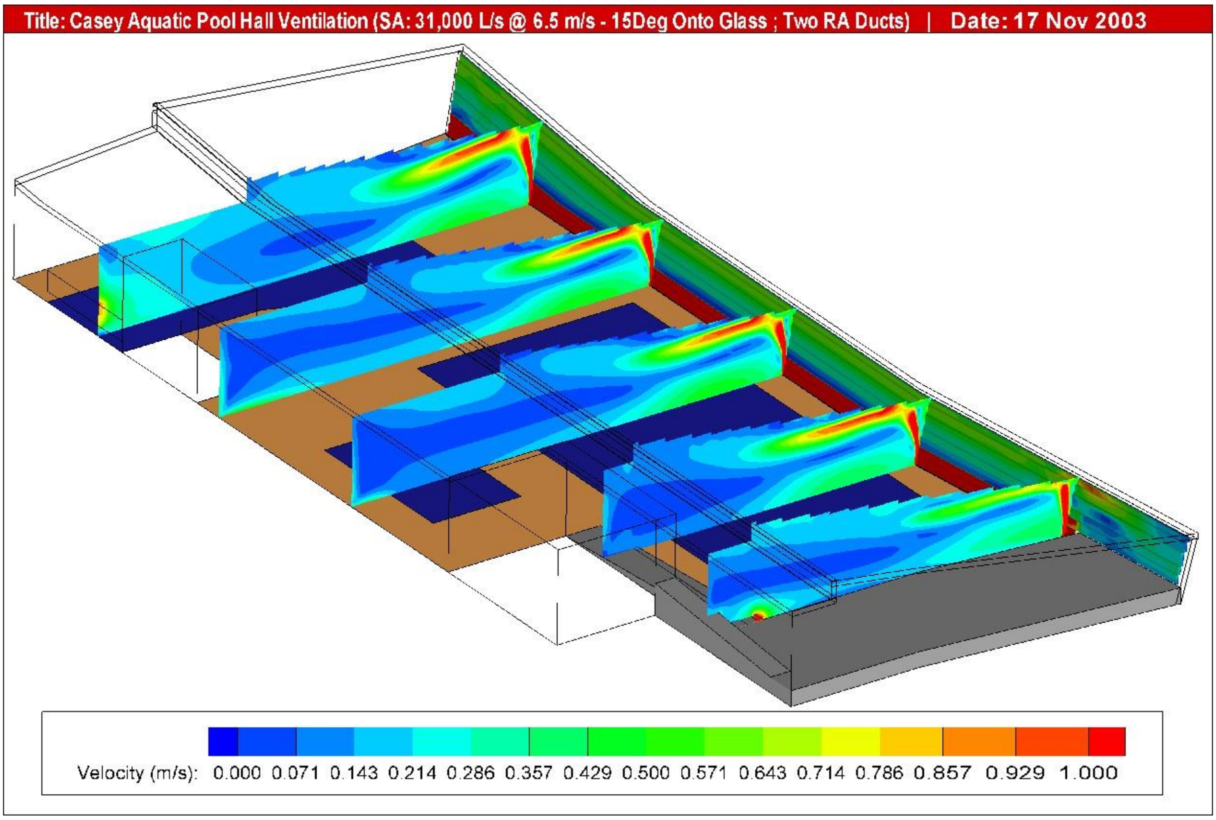


Casey Aquatic & Recreational Centre– Melbourne, Victoria

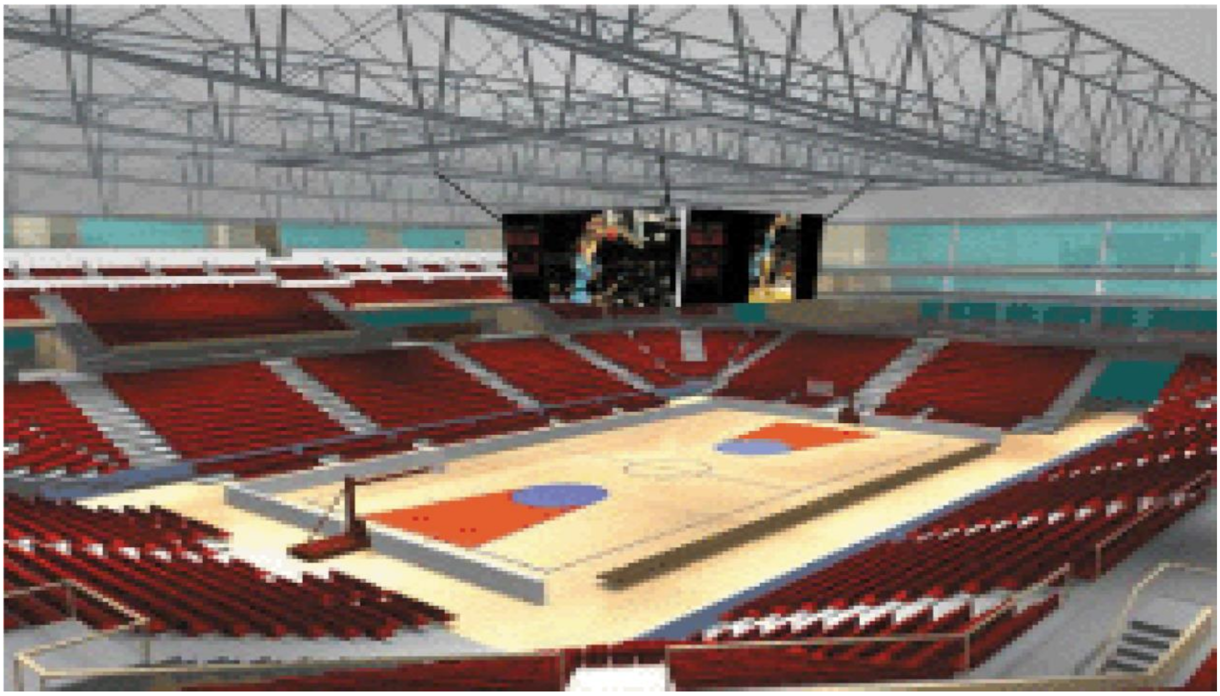
In addition to the normal concerns of adequate temperature comfort control the ventilation system design within an indoor swimming pool complex also needs to address the issue of maintaining sufficient fresh air ventilation within the occupied zones of the pool hall concourse. This is in order to provide the necessary removal of water vapour (for relative humidity comfort control) and chemical vapours (eg: chlorine) that are evaporated from the pool surfaces.

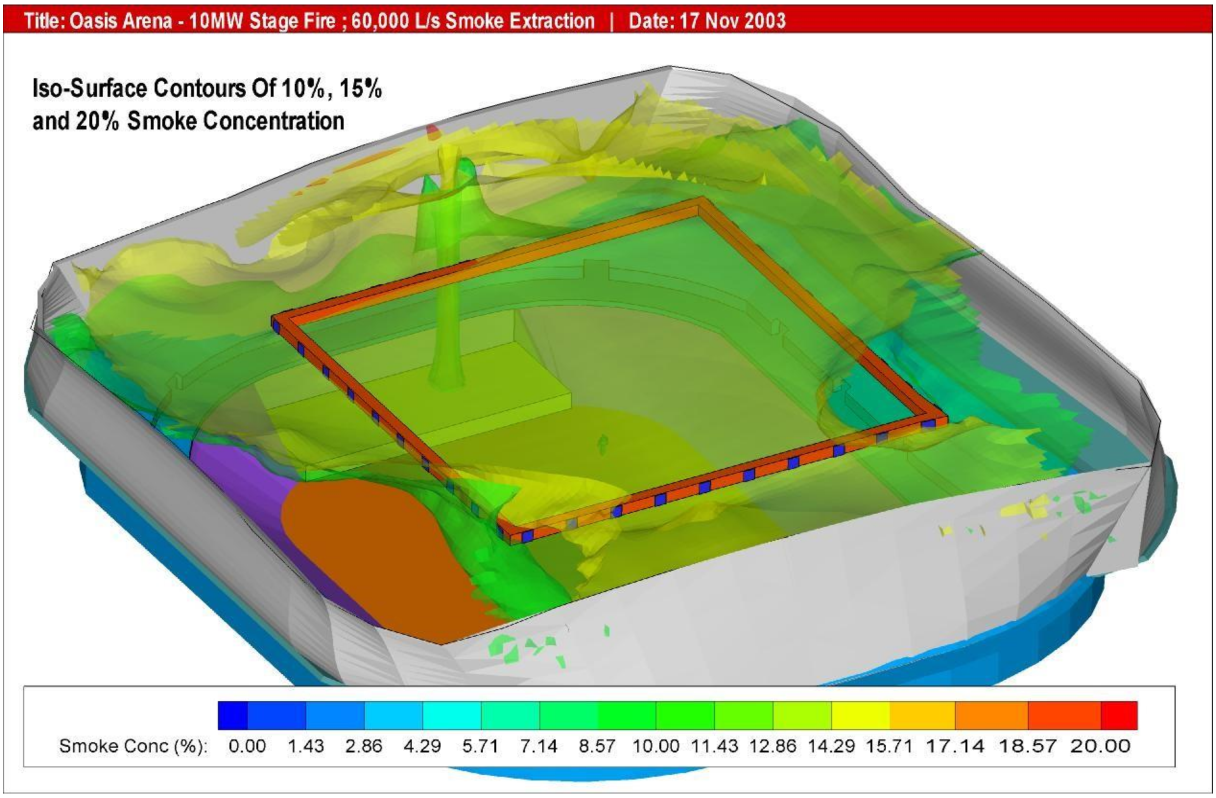


In order to assess this aspect within the recently built Casey Aquatic & Recreational Centre, a CFD modelling study was conducted. A number of different ventilation system configurations were analysed and the results were compared with each other, specifically in regards to the air movement distribution within the pool hall. In this manner recommendations were submitted to the mechanical services contractor which indicated possible areas of concern (stagnant flow regions) in some parts of the occupied zones of the pool hall.

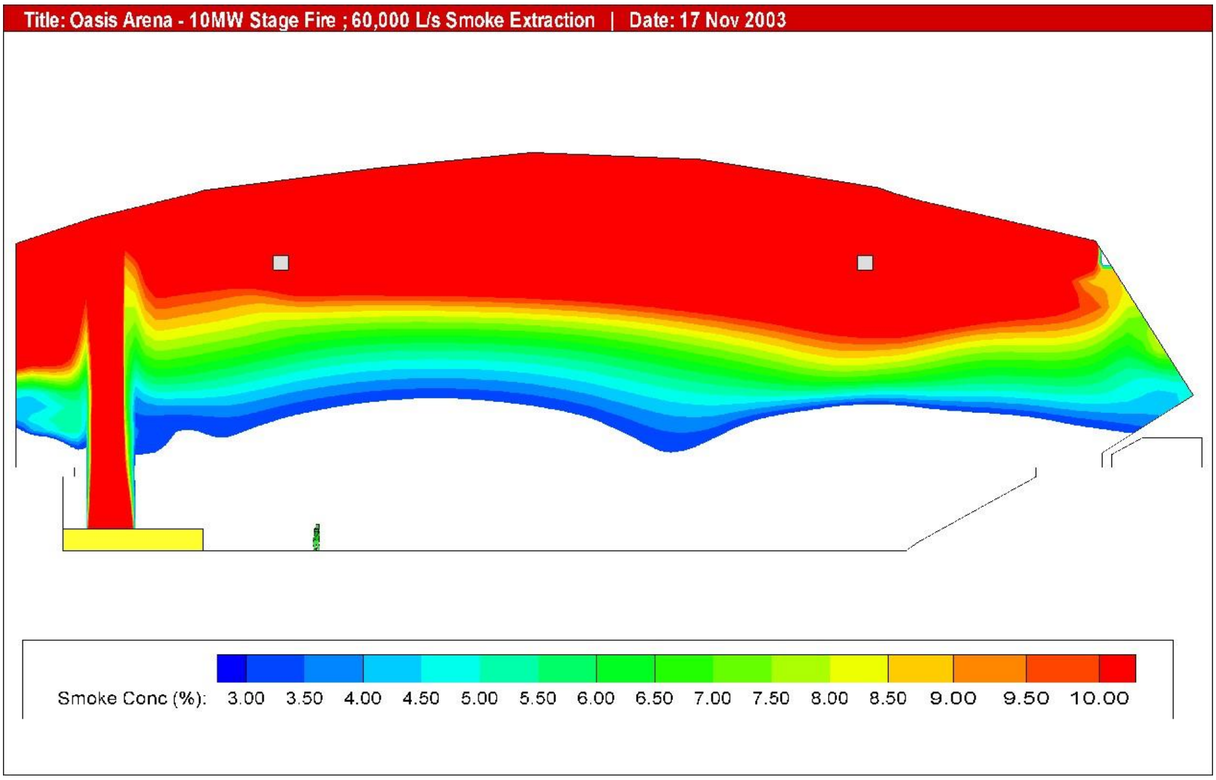


Oasis Arena– Sydney, NSW





As part of the fire engineering design process for the proposed Oasis Arena complex, in order to satisfy Building Code Australia (BCA) requirements, a performance based approach consisting of CFD modelling was conducted to ensure tenable conditions are maintained indefinitely within the concourse and vomitories. The modelling was used to assist in optimising the smoke extraction system in terms of size and capacity (which directly impacts upon the capital cost outlay) that would still comply with the regulatory requirements.



CONCLUSIONS

The use of CFD as an integral and important part of the engineering design process of sports arena and stadia has been demonstrated through several case studies. This has established issues relating to ventilation, occupancy comfort, fire and health safety and energy considerations (incorporation of natural ventilation and passive features over mechanical ventilation systems as far as possible) can be adequately addressed using CFD techniques.

It is anticipated that these types of high profile projects can be used as benchmarks for similar projects worldwide and be promoted as world's "best practise" in ensuring high patron comfort satisfaction, safety conformance and sustainable built environment design for sports arena and stadia.