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CROWD CHARACTERISTICS AND EGRESS AT STADIA

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ABSTRACT

This paper investigates emergency egress considerations of stadia by examining occupant characteristics and discussing how effective crowd management can be used to improve evacuation procedures. The findings are based on recent research on fire protection and evacuation procedures of stadia venues primarily in New Zealand.

INTRODUCTION

Stadia present unique egress challenges. A stadium may have a regular non-event occupancy of 20 - 200 people but immediately preceding and during an event these numbers could swell to 20,000 - 200,000 depending on the capacity of the venue. The logistics of facilitating this size population is already complex and coordination during an emergency evacuation only increases the complexity.

The likelihood of a major evacuation being required at a stadium over its lifetime is low due primarily to its infrequent occupation. However the potential consequences of an ineffective evacuation for such an occupancy are serious. For this reason much work has been done in several countries including the UK and the USA to study large crowd movement in stadia and other occupancies and to especially consider large crowd venues when developing building codes and venue management guidelines.

Stadia in New Zealand are small by international standards; only twelve have the capacity to accommodate in excess of 20,000 patrons. Of these, most host no more than two major events per month. Therefore, even regular event staff spend little time at a venue. Because of the infrequent demand for event staff, the majority of employees that work at a venue during an event day are supplied by contractors. Consequently the staff may well vary with different events and could be unfamiliar with the venue and the issues associated with accommodating large capacity crowds (10,000 or more patrons).

Half of the main stadia in New Zealand have been built or rebuilt in the last decade. The remainder are at various stages of modification. No stadium in New Zealand has experienced a large fire and only one venue has experienced an event that has resulted in its total evacuation. That incident was a false indication of a sprinkler head activation in a kitchen. It occurred prior to an event and did not cause significant disruption to the scheduled event.

Due primarily to the lack of incidents and the relatively minor contribution stadia make to New Zealand's building stock profile there has been little input from regulating authorities in developing or providing guidelines, standards or other documents to ensure a consistent and appropriate quality of egress management or design for such occupancies. Nor has any great amount of research been performed on high density crowd movement in order to test the appropriateness of recommended occupant densities used to calculate egress capacities for such venues in New Zealand. To the authors' knowledge the research that this paper is based on is the sum total of high density crowd egress studies performed on the New Zealand populous.

STADIUM EVACUATION

Stadia are designed to facilitate mass movement on a regular basis but it would be a mistake to assume that normal stadium egress and evacuation movement for these venues are identical.

One advantage that stadia have over other occupancy types is that they facilitate an exodus of all occupants within a short period following every event, hence egress routes are well tested for egress flow and most problem areas can be easily identified and rectified. The disadvantage to this is that occupants predetermine their egress path. Patrons often attempt to leave the way they entered the stadium, or if there is an exit that is close to a facility they wish to utilise after the event e.g. public transport, this may become a determining factor in selecting an egress path. Even in emergency evacuations occupants may not necessarily move towards the nearest exit. This may in part be attributed to a lack of familiarity with all the exits that are available around the stadium. However habit, laziness and prior experience may also play a role.

Potential components of a stadium evacuation that differ from normal egress include: -

- The availability of exits that are not normally used – these may be ignored as they are not normally available or they may be used if they provide faster egress.
- Limitations to visibility either through smoke obscuration or power failure to normal lighting, particularly for night time events – familiar pathways may be easier to negotiate.
- Audio and visual guidance – this can be employed to inform patrons of the safest egress route.
- Guided movement – stadium management may structure the evacuation to occur in stages and ushers and security may guide the crowd along certain routes.

In several stadia in both Australia and New Zealand there is an increasing awareness of the issues associated with implementing an evacuation. This has lead to the use of big screen scoreboards to advertise emergency procedures before events and during half time. In addition to this the posting of evacuation maps and instructions on tickets, at entrances and on toilet doors are all designed to raise the awareness of emergency procedures to the patrons.

ANALYSIS

Observational data was collected and analysed for 23 egress paths (EPs) from various locations around the grounds of eleven New Zealand and Australian stadia. Egress paths were selected based on recommendations and prior observation of crowd movement. The egress paths that were monitored for speed consisted of a combination of stair wells, and walkways from which data could easily be extracted. Flow rates were obtained from walkway, stair and vomitory egress paths. Details on specific egress paths are discussed elsewhere[1]. Data was collected during and following rugby union football games and Australian football league games. The data collected exemplified a variety of egress characteristics.

Flow Rates

In conjunction with extracting flow rates and crowd density from raw video footage and measurements, calculations using recommended values were performed for a selection of the egress paths. In comparing observational data and recommended values it is apparent that there is some disparity between the results obtained and those of other studies in the literature.

Figure 1. Crowd flows on walkways.

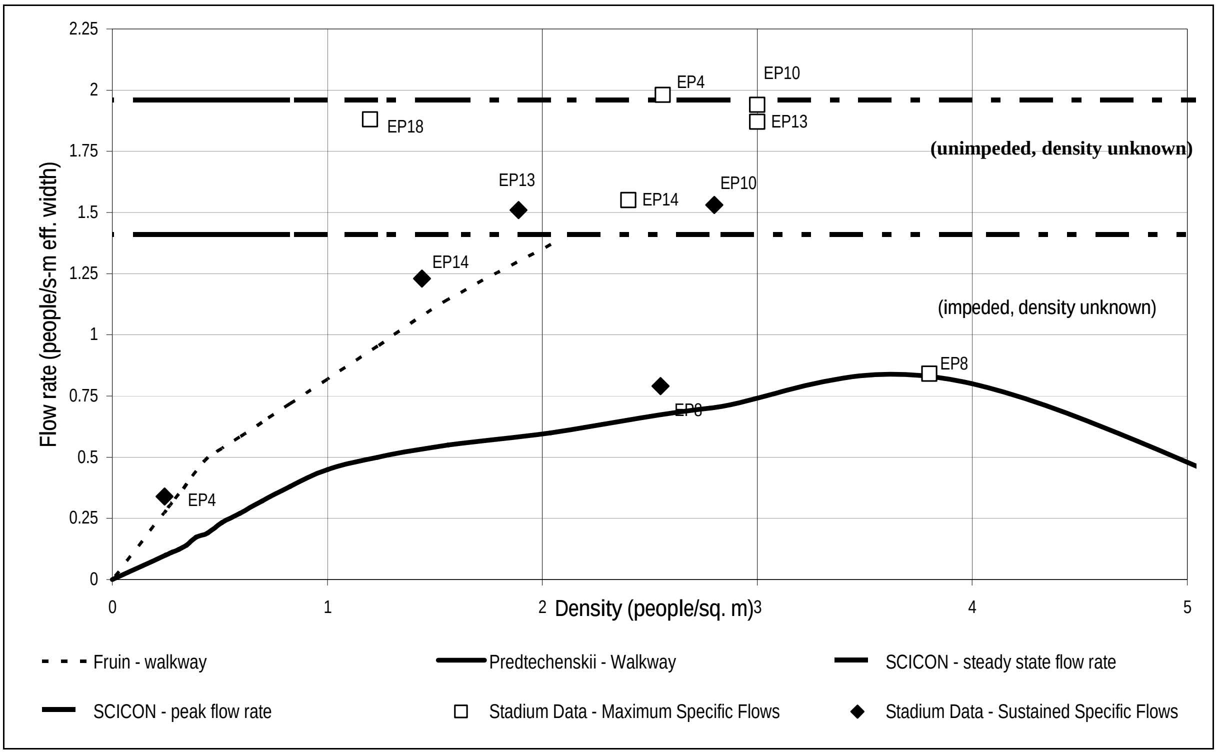


Figure 1 shows flow density relationships as established by two researchers; Fruin[2] and Predtechenskii *et al*[3]. Work by these researchers has formed the basis of much current understanding of pedestrian flow rates that underlies current practice in emergency movement calculations. Maximum and steady state flow rates from an egress study conducted at stadia in the UK by Poyner *et al* (SCICON)[4] are also shown. The flow density relationship for Poyner *et al*'s study was not explicitly stated; hence only discrete values are shown on the graph for this data. Plotted over these relationship curves is experimental data obtained during regular egress at stadia around New Zealand in 2002[1]. Diamonds indicate sustained flow rates that were obtained from the video analysis of egressing crowds and squares indicate maximum specific flows that were recorded. Their labels indicate the egress path that they relate to.

From Figure 1 it appears that although sustained flow at stadia mimics Fruin's general curve profile, higher speeds can be achieved with a high density crowd than are indicated by either Fruin's or Predchetenskii's data. Maximum specific flow rates show less of a pattern but consistently high values were achieved. This indicates that at high density the density flow rate relationship may break down and behavioural factors, as discussed later, may become determinant in influencing flow rates.

Calculated Flow

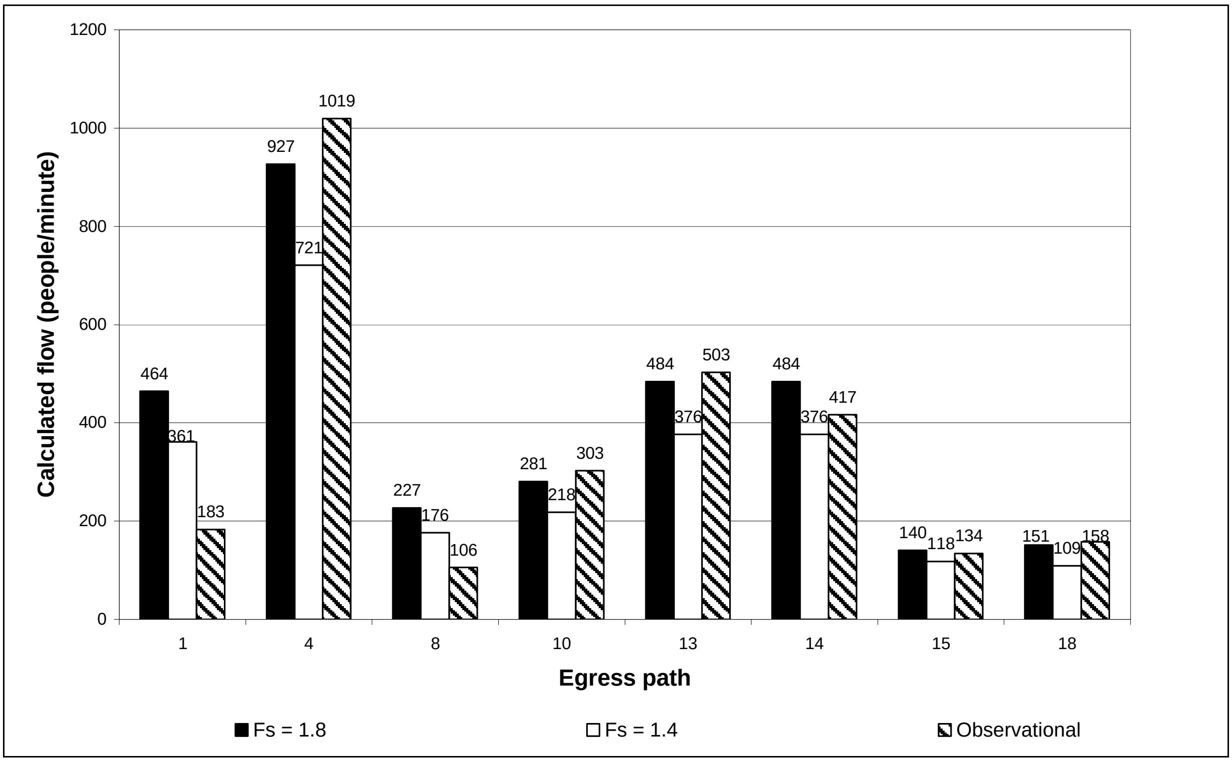
By applying the maximum walking flow rates recommended by The SFPE Handbook of Fire Engineering[5] based on Fruin's work and the UK Guide to Safety at Sports Grounds[6] (commonly referred to as the 'Green Guide') based on Poyner *et al*'s study to the effective widths of pathways in the New Zealand study, a comparison of calculated flow rates for eight walkways was obtained.

For the analysis shown in Figure 2, the equation

$$F_c = F_s W_e \qquad [1]$$

was used, where F_c = calculated flow, F_s = specific flow and W_e = effective width. Effective widths varied for individual egress paths based on presence of hand rails. The results obtained from comparing standard egress movement values and observed egress movement show stadium egress movement to be unique. Standard methods of anticipating egress movement when applied to stadia appear to be more conservative than actual movement. Although this study only produced a small sample of egress values for stadia, these results were sufficient to determine that crowd movement at stadia is a special case. Stadium egress therefore deserves further consideration than is currently given in the NZ Building Code.

Figure 2. Comparisons of calculated flows for walkway egress paths.



It must be noted that the observed egress paths did not maintain optimum usage throughout the egress and so the values based on Poyner's and Fruin's specific flow values should both be greater that that which was observed. In practice this was not the case and several egress paths experienced markedly higher flow than that anticipated when using an F_s value of 1.4 persons/s-m effective width (Fruin's value). A much better correlation occurred when using an F_s value of 1.8 persons/s-m effective width (Poyner *et al*'s value).

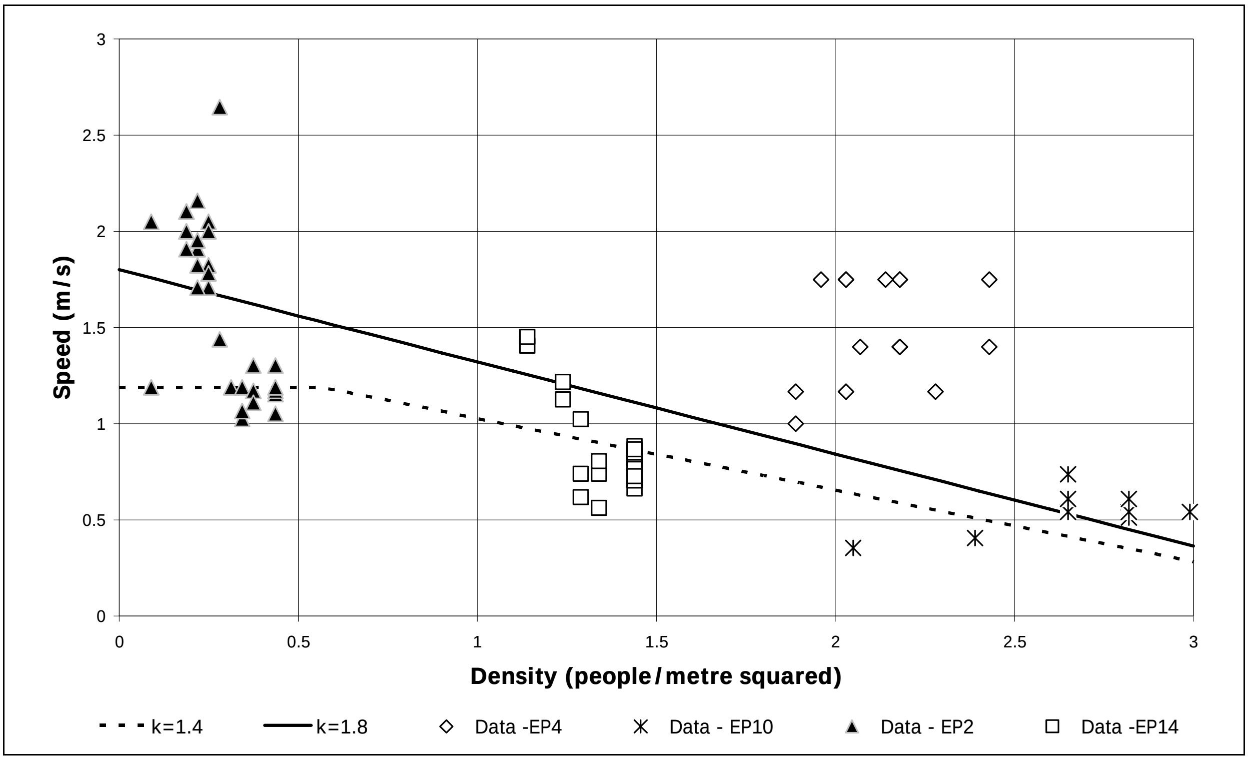
Figure 3 shows speed density data that was obtained for individuals traversing specific egress paths during this study. This data and observations of crowd movement support the hypothesis that large crowd venue occupancies require specific consideration in the context of evacuation planning.

The equation

$$S = k - akD \qquad [2]$$

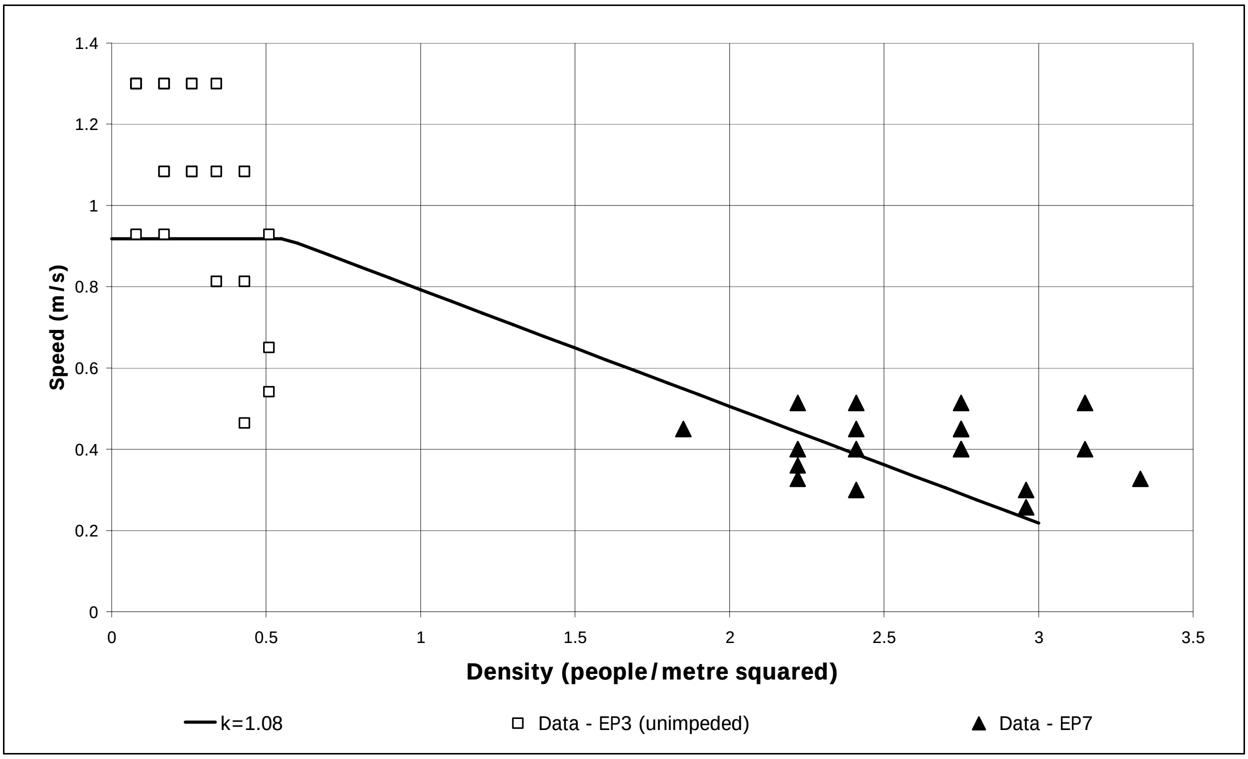
where S = speed, a and k = constants and D = density was used to establish the egress speed as a function of density curves for movement speeds consistent with Fruin's and Poyner *et al*'s values. A significant scatter is apparent from this data shown in Figure 3 but overwhelmingly there is a trend towards higher speed movement than would be predicted by using k = 1.4.

Figure 3. Movement speed as a function of density for several walkway egress paths (EP) at stadia.



Similarly Figure 4 shows the movement speed as a function of density for two stairwells investigated in the study. Using the recommended k value of 1.08 given in Table 3-14.2 of the SFPE Handbook a reasonable consistency with the data is evident.

Figure 4. Movement speed as a function of density for two stairway egress paths (EP) at stadia.

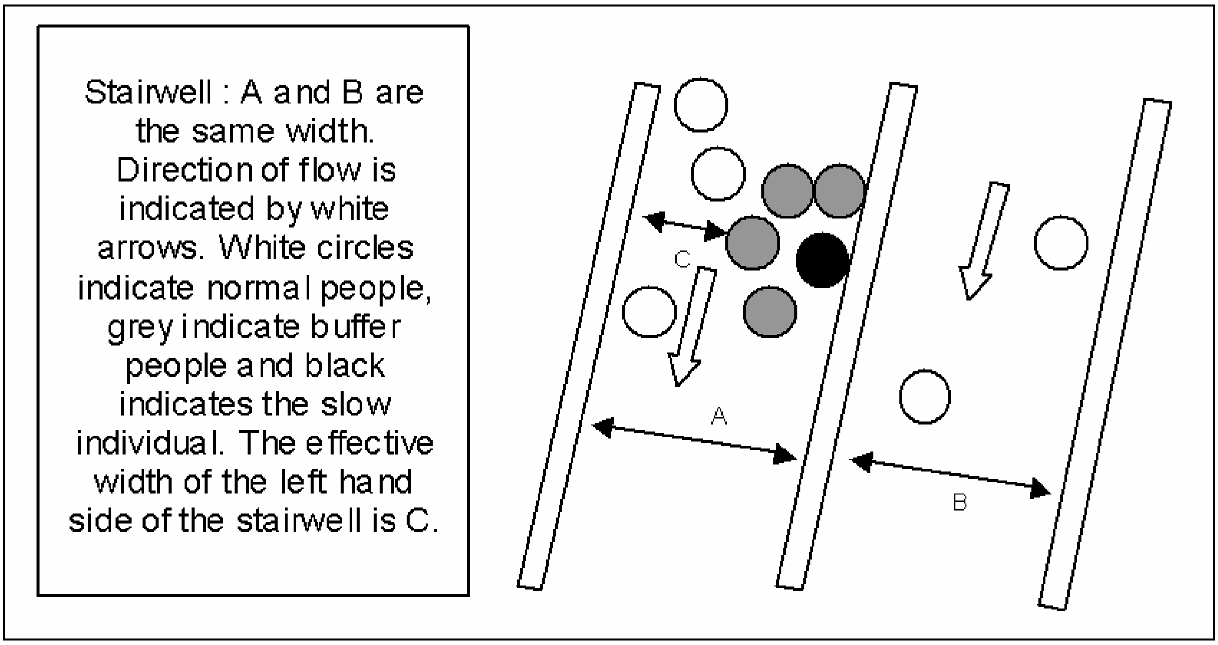


Blockages in Egress Paths

As mentioned previously, because of the movement patterns of stadium patrons most congestion points can easily be identified and addressed. There is however still the potential for temporary congestion points to arise. Observations of stairwell movement in this study highlighted the potential for congestion to occur around 'weak' individuals within the crowd. Figure 5 illustrates how a temporary congestion point can occur along an otherwise unobstructed egress path. One individual shown in black experienced difficulty descending the stairs and those around the individual (lighter grey) slowed to the same pace in order to protect the 'weak' individual from the rest of the crowd. This narrowed the available stairway for other patrons and significant variance in descent times between different sides of the centre rail resulted. If there were a large number of 'weak' individuals occupying the stadium this could have a major effect on egress movement. However through utilisation of closed circuit television (CCTV) stadium management can identify these points and utilise ushers to redirect flow to other egress paths.

In the case of an actual emergency part of the concourse may become blocked. If this happens, for an evacuation to be effective, the occupants must be redirected. With a total evacuation it is more difficult to redirect occupants than in a staged or partial evacuation.

Figure 5. Temporary blockage of stairwell by a 'weak' individual.



DISCUSSION

Acceptance of High Densities and the Role of Social Psychology

It has already been established that an egressing stadium crowd is unlike most other moving crowds[7]. This is evident through the crowds ability to move at a higher than predicted speed for given density. In observing movement inside and outside of stadia it can be speculated that behavioural factors play a significant role in this disparity.

These factors can be summarised as: -

- Lack of visual stimulus
- Lack of choice
- Acceptance of a collective identity
- Common focus
- Acceptance of loss of personal space

It is speculated that the individual in a stadium crowd is not of the same mindset as an individual in the likes of a casino or bus terminal crowd. People gather at a stadium to experience a common entertainment event of limited duration and then disperse.

During the event individuals expect to become members of a crowd. Part of this transition includes taking part in activities that increase the cohesion of the crowd, such as Mexican waves. Activities such as this temporarily diminish individual characteristics in favour of a collective personality. Following an event there is seldom a reason to linger and the majority of the crowd, still comfortable with a collective personality, attempt to leave as quickly as possible. Stadia are designed to facilitate this mass exodus and retailers along the concourse close up prior to the end of an event.

With no distracting shop frontages, concessions or alternate pathways to divide a patron's attention they can and do focus entirely on getting out. In this vein it may be speculated that the density of the egressing population is such that this is compounded and occupants conform to the path of least resistance, moving accordingly.

Even where patrons are at cross paths movement remains rapid. Patrons appear to keep their head up and look straight ahead. Streams of crossed path movement may develop, often in single file with individuals walking with one shoulder leading so as to take up less space as they cross the main flow. Gaps are quickly closed up and little regard for personal space is apparent.

Once patrons exit the grounds and enter the street individual characteristics return. Movement rate slows, individuals look around more frequently, people look at their feet and the footpath more frequently and they visibly re-establish and maintain interpersonal distances. A very visible change in behaviour is apparent in a patron during and following their egress. It is speculated that this is more marked than for most other egressing populations.

Management Techniques

Because of the unusual flow characteristics of stadium crowds it is important that an appreciation of these peculiarities be employed in estimating egress capacities either by calculation or simulation in order to accurately predict emergency movement requirements. In adopting a specific flow of 1.4 persons/s-m effective width, egress estimations are likely to be more conservative than necessary and the structure may be over designed. It may therefore be appropriate for New Zealand to adopt or endorse a document such as the Guide to Safety at Sports Grounds[5] as an appropriate reference to source movement rates when designing stadium structures and developing their evacuation plans.

Lack of guidance in this area has flow on effects in how event management and venue management operate. Because no agreed common guidance is readily available, a wide variation in the understanding and implementation of evacuation requirements and application of fire protection at New Zealand's main stadia has developed. The role management plays is key in affecting appropriate measures to ensure the safety of patrons in the event of a significant fire. Because alerting and fire protection systems are closely linked to effective evacuation, structures that accommodate large scale populations need to consider this in developing crowd management strategies. The variation in the level of fire protection afforded to, and evacuation planning between stadia, indicate that greater guidance is required in order to ensure a consistent level of safety for patrons.

Stadium management have applied an ad hoc adoption of overseas guidelines and other documents in conjunction with occupational safety inputs in order to meet the requirements of the New Zealand Building Code and manage normal occupant usage. There is no policing of management strategies beyond accrediting evacuation plans for a venue. Hence, inconsistencies and compromises to the intent of adopted documents can be found at a number of stadia. Adoption or recommendation of a common guideline such as the Green Guide would assist in consolidating crowd management and evacuation policies in a way that provides a consistent level of protection to patrons in fire and other situations as per the intent of the Acceptable Solutions in the Approved Document for New Zealand Building Code[8] and the Fire Safety and Evacuation of Buildings Regulations[9].

Despite the lack of standardised guidance, the level of egress planning incorporated into event management at stadia is for the most part comprehensive and in some cases quite innovative. In three stadia egress time goals have been set and event egress times are evaluated in order to identify ways to continually improve egress facilitation.

Passive Egress Management

The available tools for facilitating patron egress have expanded over the last decade. As stadia are upgraded or rebuilt the adoption of fluorescent markers, emergency warning and intercommunications system (EWIS) and improved structural design have all become incorporated into facilitating egress management to varying degrees. The use of big screen advertising and improvements in printing technologies have increased the means by which information can be relayed to patrons. Reminding patrons of evacuation procedures through audiovisual advertisements and providing evacuation instructions on tickets are two ways in which passive egress management has evolved.

Active Egress Management

Active management techniques have also improved. Rather than a crowd control policy crowd management has increasingly been employed. The ability to communicate with patrons has enabled partial and staged evacuation procedures to be developed and through more closely integrating security and event management the ability to identify potential egress problems and resolve or work around them has also been enhanced.

Integrating Evacuation and Response Movement

With the improving technologies that are available for egress management increasingly complex plans can be developed. In two stadia this has been extended to provide separate access to stadium levels for response personnel distinct from pathways available for egressing patrons. It is anticipated that this will improve response time for incidents.

Coordination of response agencies with egress management has been further enhanced by the adoption of Coordinated Incident Management System (CIMS) training by stadium security and event management staff at some stadia. CIMS is a nationally recognised incident management system that is used for multi-agency response coordination across the emergency services and various other agencies in New Zealand. It provides a coordinating structure to centrally manage a large event. By introducing this to stadium event management and integrating it into emergency planning it is anticipated that egress management can be integrated into the wider response that would occur if the stadium was compromised.

CONCLUSIONS

In most of the observed egresses in this study, crowd movement was expeditious. This implies that for the most part egress is managed appropriately. Safe, timely evacuations should therefore be achievable. The fastest clearance times were achieved by stadium management attempting to meet an eight minute evacuation goal. Stadia with longer evacuation times had no such goal. The recommendation of a standard acceptable evacuation time for stadia may be helpful in encouraging all stadia to improve their egress capabilities.

Egress management has become increasingly integrated into event operations which has allowed for an overlap of resources from other areas such as event facilitation. This clearly has benefits and should be encouraged in order to customise egress responses to situations as they arise.

Crowd movement for very large high density crowds is unique. As such, special consideration should be given to guiding crowd movement and customising evacuations in order to accommodate a range of evacuation scenarios. Assumptions in developing evacuation plans must be based on appropriate crowd movement profiles in order to appropriately mimic stadium crowd behaviour.

Further study of densely packed, large scale entertainment crowds is needed to quantify the egress movement relationships for stadia and determine whether these relationships are common to other densely populated, large scale entertainment venues such as indoor arenas.

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