Structural STEEL Casebook

onesteel

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"Gabba"...the story continues

Extensive Fire Engineering research support has provided a cost effective, safe solution for the redevelopment of the Brisbane Cricket Ground, utilising an unprotected steel frame.

The transition is almost complete. Following on from the construction of the multi-award winning Northern Stand in 1995, the Brisbane Cricket Ground has undergone two further stages of construction with the completion of the Eastern and Western Stands (Stage 4) and the Southern Stand (Stage 5) in late 1999. Presently undergoing Olympic overlay works, the 37,000 seat world class stadium is being readied to host the Olympic Football (soccer) tournament.

Architecture

The masterplan undertaken in 1993 by Daryl Jackson Pty Ltd, in association with the International Facility Corporation, recommended that the design should:

- Have a structure that was incrementally expandable
- Be related to the Queensland ambience
- Have a ground capacity of 35,000.

The progressive development of the ground and the continued involvement of the architect from masterplan stage through to its present highly acclaimed state, demonstrates how successfully the architects have met the original brief.

To suit the revised master planning requirements, a decision was taken during the early construction stages of the Eastern Stand to remove the light tower and increase the capacity of the ground. A mid tier level was therefore added to the Eastern and Western Stands (and the later Stage 5 Southern Stand). Stage 4 planning requirements necessitated that the Eastern Stand encroach on the adjacent school ground. The consequent negotiated design reduced the extent of this encroachment, and land rights were transferred to the Brisbane Cricket Ground Trust in exchange for financial compensation.

The 18 bay Eastern Stand has 4 levels, similar to the Northern Stand:

- L1 - food and beverage store rooms
- L2 - public entry, concourse and corporate entries
- L3 - corporate suites and function rooms
- L4 - public concourse that services the upper tier.

Construction of the Eastern Stand necessitated the relocation of the Queensland Cricketers Club to the Northern Stand Level 3 function areas, after suitable refurbishment.

The stage 4, 5 bay Western Stand is similar to the Eastern Stand, but includes ground maintenance facilities within Level 1, and the relocated Hill scoreboard.

The nomination of the Brisbane Cricket Ground, or the Gabba as it is widely known, by the Queensland Government as the venue for the Olympic 2000 soccer matches was the catalyst for development of the next stage of construction. Stage 5 incorporates a 15 bay Southern Stand extending from the end of the 5 bay Western Stand to the western end of the existing Lions Social Club. This stage required the removal of the famous (infamous?) Hill, an area much loved by the populist poet Rupert McCall in his heyday. The Clem Jones Stand was demolished and the Hill scoreboard relocated to the Western Stand. According to architect Gary Carter of Daryl Jackson Pty Ltd, the ability to

relocate the large scoreboard into the Western Stand construction without compromising the construction timetable is testimony to the flexibility of steel framing.

Stage 5, 15 bay Southern Stand:

- L1 - Lions and visiting team change rooms and warm up areas
- L 2 - public entry and concourse, Lion's Football Department, sports medicine clinic with indoor pool
- L 3 - corporate suites and large function room
- L4 - public concourse and upper tier circulation
- L5 - Lion's AFL Club offices.

The ground operated very successfully at full capacity for the recent Australia versus Pakistan one-day cricket match. Gary believes that the use of structural steel as the main framing material has contributed to the success of the project. He is particularly pleased that the architectural vision for a light visual frame has been so gracefully achieved in the difficult cantilever structures over Stanley Street.

The Gabba played host to the recent Australia v Pakistan one-day match.

Description	No. of Bays	General Seating	Corporate Suites (12p)	Corporate Boxes (8-10p)	Total Seating	No. of Seating Tiers	Total Cost ($M)	Av. Cost per Seat ($)	Steel Tonnage
Stage 3 - Northern Stand (built 1995)	15	9,132	19	27	9592	2	36.8	3836[1]	450
Stage 4 - Eastern Stand	18	13,144	39	0	13612	2 & 3	35.7	2170	559
Stage 4 - Western Stand	5	2,445	11	30	2835	3	combined	combined	201
Stage 5 - Southern Stand	15	10,455	20	31	10961	3	41.5	3786[1]	660
TOTAL	**53**	**37,000 Total Seating** Stages 3-5					**$114M** Stages 3-5		**1870T**

Note 1: The cost per seat for Stages 3 & 5 is significantly higher than Stage 4 due to extensive basement construction works.

Structure & Construction

Watpac Australia Pty Ltd (Watpac), having built the existing Northern Stand in 1995, successfully tendered for the following Stage 4 contract and were appointed as Managing Contractors for the works. This comprised the 18 bay Eastern Stand and the 5 bay Western Stand, with the developed design forming the basis of the scope of work. The Eastern Stand was completed in March 1999, one month earlier than scheduled, and the Western Stand was delivered on time for match use in May 1999. Watpac were again successful tenderers and were appointed by the Trust to manage the design, documentation and construction of Stage 5 for agreed fees, preliminaries and margin. The design consultants were novated to Watpac. A Guaranteed Maximum Contract Sum was developed and agreed, and a share of savings arrangement implemented.

Structural steel was used extensively throughout all stages of construction as the basic structural framework to support the seating, concourse and back of house amenity areas. The innovative design of the initial elliptical grid for the master plan by Daryl Jackson Architects required economical design solutions. Watpac, in conjunction with structural engineers Robert Bird & Partners and with input from OneSteel (formerly BHP Steel), decided upon structural steel to provide these solutions.

According to Watpac Design Manager, Gary Gisik, structural steel not only provided an innovative design solution for the primary structure, but also delivered the following additional benefits:

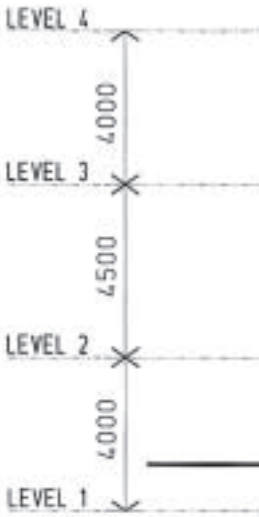
- Enhanced the architectural intent developed by the architect's master plan.
- Provided cost effective design solutions to support seating plats and large spans for suspended concourse areas.
- Maintained the majority of structural works being prefabricated off site, thereby eliminating congested storage of material on what was an extremely tight site.
- Enabled pre-finished structural and architectural elements to be combined and erected in single phases, which proved to be time effective. This also enabled immediate flow of subtrades to pre-finished areas.

"This last point was of particular benefit when constructing the majority of works over Stanley and Vulture Streets where access and traffic restrictions meant that speed of construction was paramount," Gary said.

"The use of structural steel as the major building element was further supported by the introduction of the project specific Fire Engineering Design Brief (FEDB)," he said.

"The introduction of this brief enabled the level of fire risks to be established based on the nature of occupancy and building classification class. The FEDB provided economical design solutions which were carried throughout the design process and further encouraged the extensive use of structural steel as the primary framework without further fire protective site treatment."

Design and construction challenges posed by the land-locked nature of the site to the north were overcome previously by cantilevering the existing Northern Stand over busy Vulture Street. The new Southern Stand posed an even greater challenge due to the need to cantilever 13m over the four-lane Stanley Street. Consulting civil and structural engineers for Stages 4 and 5, Robert Bird & Partners Pty Ltd, recreated the structural framing solution they adopted on the previous Northern Stand. The system was modified to accommodate new design features such as an additional tier to the Western and Southern Stands and part of the Eastern Stand, the relocation of the Hill Scoreboard to the Western Stand and the dramatic cantilevering of the Southern Stand over Stanley Street.



The distinctive steel signature of the Southern Stand.

Typical Steel Framing

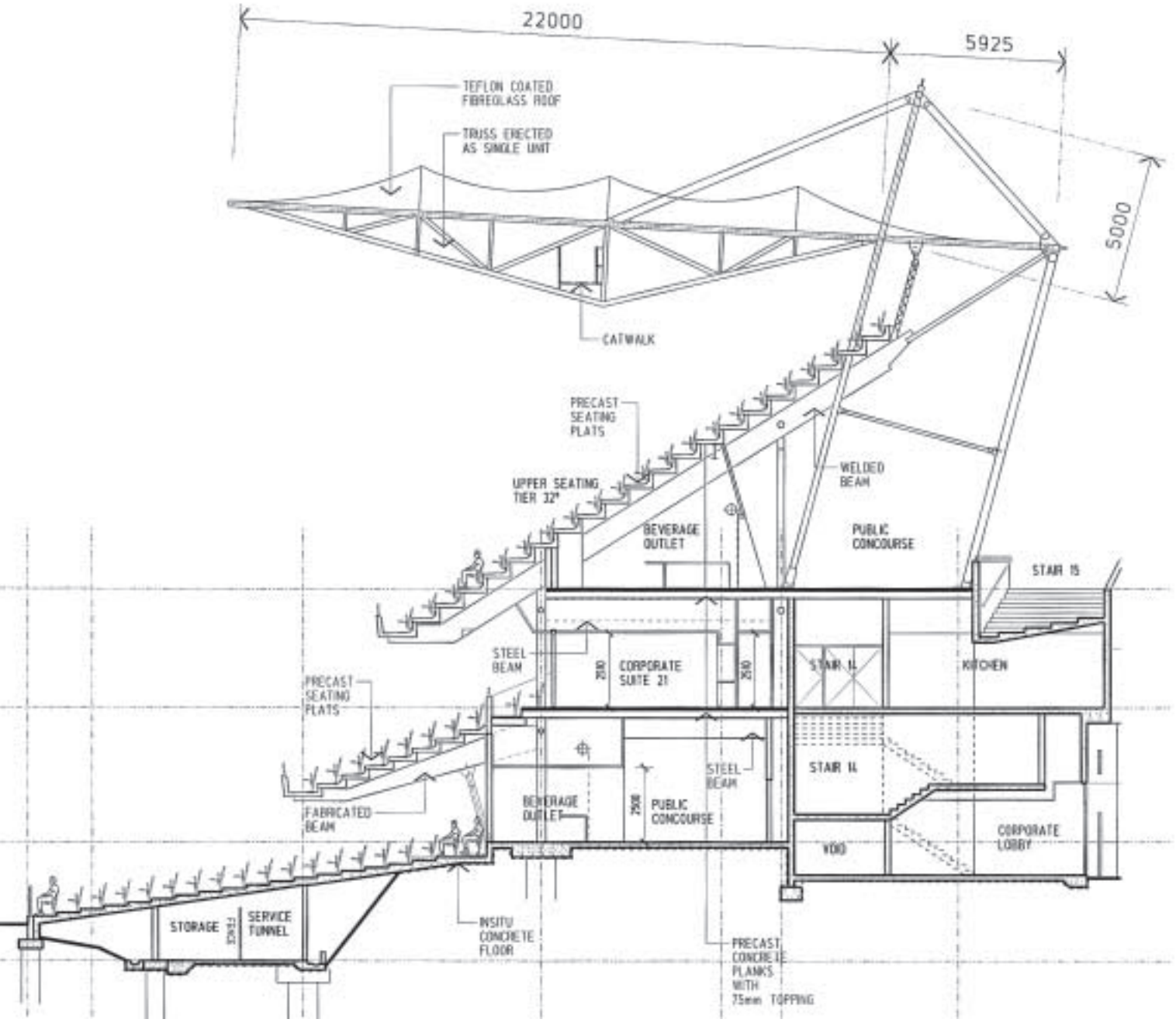
Eastern Stand, Grid 16-24
(Structure is similar to the existing Northern Stand)
• Upper Tier Raking Girder: 800WB122 - interior span of 8m with a 5m cantilever towards the playing field and a 4.5m cantilever at the rear of the stand.
• Lower Tier Raking Girder: 700WB115 – continuous over two spans of 8m each.
• Back-of-House Floors: 700WB115 with 20 Flange Plates – continuous over two spans of 8m and 6m.

Eastern Stand, Grid 25-34
• Upper Tier Raking Girder: similar to Grid 16-24.
• Middle Tier Girder: Fabricated girder, 12 thick web varies 980 to 415mm deep, 400x36 flanges – cantilevers 6m towards the playing field and has a 2.5m backspan.
• Back-of-House Floors: Similar to Grid 16-24.

Western Stand
Similar to Eastern Stand Grid 25-34.

Southern Stand, Grid 43-51
• Upper Tier Raking Girder: 800WB146 - interior span of 9.5m with a 4m cantilever towards the playing field and a 4.5m cantilever at the rear of the stand.
• Middle Tier Girder: Fabricated girder, 12 thick web varies 980 to 415mm deep, 400x36 flanges – cantilevers 4.7m towards the playing field and has a 2.2m backspan.
• Back-of-House Floors: 700WB115.

Southern Stand, Grid 52-58
Similar to Eastern Stand Grid 25-34.



Eastern Stand section - Bay 26.

Open for business. The redevelopment of the Gabba is almost complete.

The raking girders and steel beams are supported on steel columns comprising circular hollow sections and universal columns. Precast pre-tensioned concrete seating plats span distances of 8m to 11m between the raking steel girders. The horizontal floors (Levels 3 and 4) beneath the seating tiers comprise 250mm and 300mm thick precast concrete hollow-core panels, also spanning 8 to 11m, and topped with 75mm thick concrete.

The roof is supported by steel trusses that span 11m from a main mast support point at the rear of the stand to a suspension point, and then cantilever a further 11m towards the playing field. The mast and stay assembly efficiently redistributes the cantilever roof loads into the main building frame.

An interesting feature of the truss is the use of the 460UB67 top chord with the web horizontal to act as a gutter to take stormwater run-off from the fabric roof. These gutters in turn are drained by a siphonic roof drainage system, which discharges into an underground pipe.

Fire Engineering

Existing Northern Stand – fire engineering revisited

The existing three storey Northern Stand is not sprinklered and, under the deemed-to-satisfy requirements of the Building Code of Australia (BCA) is classified as Class 9b and 5, requiring Type A construction and an FRL of 120 minutes for the structure.

An application was made to the Queensland Building Tribunal to vary the building regulations to permit the use of fire engineering analysis and unprotected steel framing. An analysis of the effects of fire on the structural steel components (carried out by BHP Research) accompanied the application. The analysis considered the effect of a non-sprinklered 'flashover' fire in various parts of the building. This was done by using methods that take into account the fire load appropriate to the particular area, the ventilation or openings available and the size of the various enclosures. The presence of ceilings was recognised and their beneficial effect on reducing steel temperatures was taken into account.

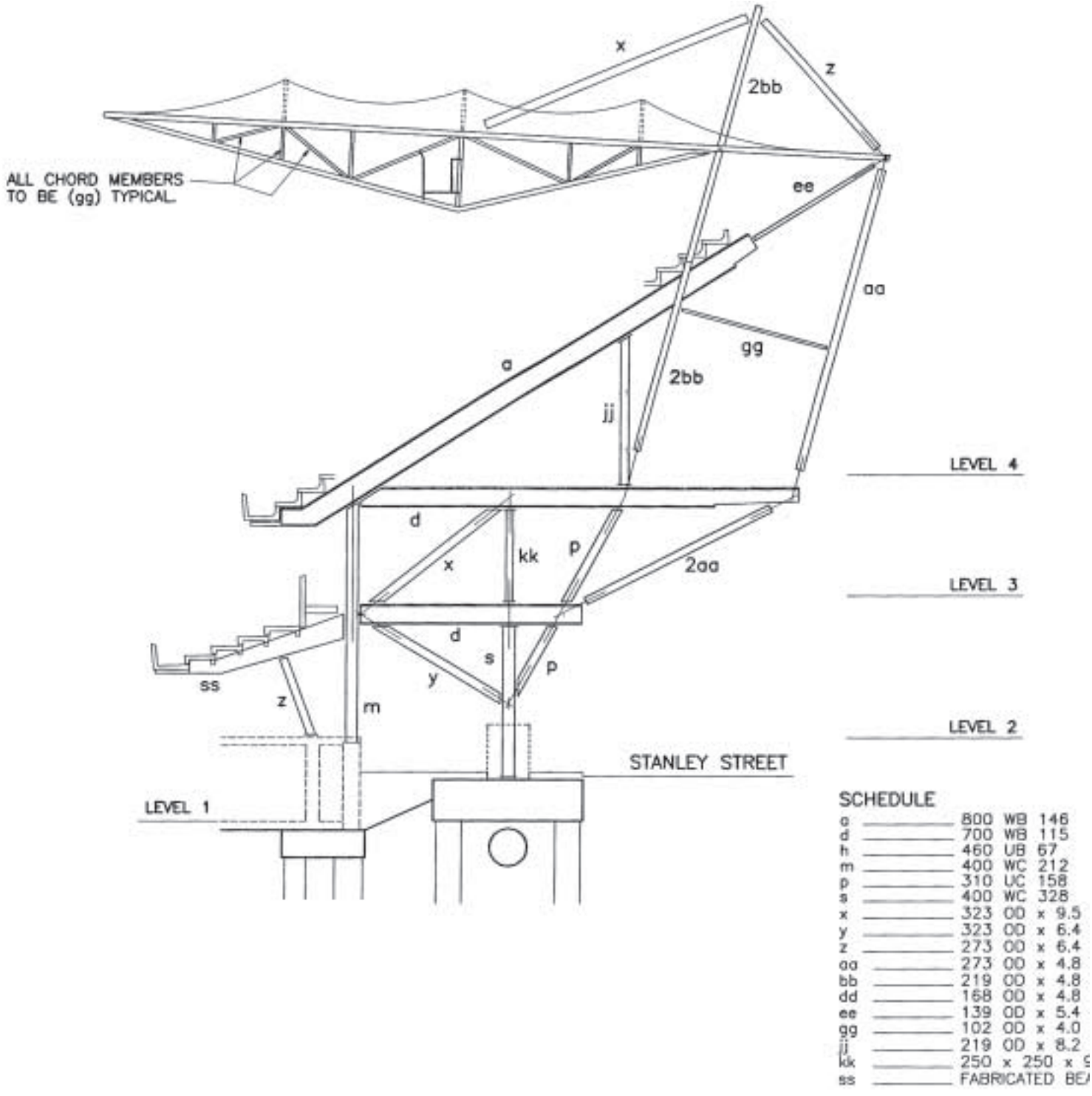
The BHP report *only* addressed the issue of structural adequacy and showed that unprotected steelwork would perform adequately in fire and could be used in most locations within the structure. The application was approved, enabling savings of approximately $0.5M in the cost of passive fire protection to steelwork.

In summary, the Northern Stand is not sprinklered. It incorporates a smoke exhaust system in the Level 2 concourse and the structure comprises generally unprotected steel. A more detailed account of the fire design is to be found in BHP Structural Steel Casebook No.13, November 1996. Following on from the experience of the Gabba Northern Stand, and other major stadia, BHP published "The Design of Sports Stand Buildings for Fire Safety" [Ref 1].

New Eastern, Western and Southern Stands - fire safety and the things that really matter

The proposed encirclement of the Gabba with grandstand construction meant that the resultant building was much larger than the existing Northern Stand. This raised questions about the need for compartmentation and indeed whether the owners and operators could afford to have a major fire in such a public building. It also raised questions as to whether a sprinkler system should be incorporated in the buildings, even though the BCA deemed-to-satisfy regulations do not specifically require it.

Grandstand construction differs from that of a typical public or office building situation in that it is usually of open layout, has generally low fire loads and is infrequently occupied. The risk to life safety and the risk of property damage and interruption of operations are minimised if fires are kept small. United States retail building fire statistics show that the greater the recorded spread of flame of the fire (which is generally reflective of the size of fire), the greater the likelihood of death. Thus sprinklers - which keep the fire small - have a very significant positive effect on life safety, greater in fact than other measures such as structural fire protection or smoke detection.



Typical steel frame (Grid 46) - Southern Stand.

What other factors are important in keeping the fire small? It is also known from fire statistics that the majority of fire starts in a building will not develop further due to self-extinguishment, or early fire fighting action by the occupants, staff and perhaps the fire brigade. It is found that 97 per cent of fires will not become threatening fires - even if the building is not sprinklered. The provision of staff training and occupant fire-fighting facilities will maintain or possibly improve this high percentage. If sprinklers are incorporated, then the probability of having a threatening fire is much less again.

What level of safety is required for these buildings? The safety level associated with a building is a function of the likelihood of a threatening fire and its consequences. How likely is it then, that a threatening fire - defined as one which is capable of extending beyond the area of fire origin - will occur during a major event? This has been estimated from [1], which for the Gabba construction gives an average probability of one such fire in every 1700 years. In order to understand the significance of this number, it is useful to hypothetically assume that such a fire (given no fire prevention measures) could result in up to 50 deaths[1] . It is interesting to note that this assumption results in an average fatality rate per person per year that is about 100 times less than that associated with driving a vehicle on the road - a risk that most of us are prepared to take.

The above outcome begs the question: should we design for a threatening fire at all? Ref [1] recommends that for a non-sprinklered building, the design fires should be those associated with flashover in any of the relevant enclosures. This will further improve the level of safety. If the building is sprinklered, then the level of safety will be significantly greater, as in this case, the probability of having a threatening fire is reduced to one fire in every 85,000 years. In that case, the design fire, according to [1], can be taken as the sprinklered fire. The implications of the above deliberations are now considered specifically in relation to the new Eastern, Western and Southern Stands.

Fire Walls

From a deemed-to-satisfy regulatory point of view, firewalls may be introduced to reduce the compartment size, in order to:

- eliminate the need for sprinklers
- reduce the hydrant capacity required
- eliminate the need for smoke control.

Fire statistics show that compartmentation within buildings such as these is not effective in preventing the spread of fire. Perhaps this is because all compartments have significant openings at their boundaries and these represent a weakness, or that the fire is so large by the time the compartment boundaries are reached, that it cannot be effectively contained. Openings within firewalls are protected with fire doors, which are obviously necessary in order to attempt to maintain compartmentation. However, the presence of these doors may present a natural obstruction to the occupants who are trying to evacuate. Thus, from the point of view of enhancing the likelihood of successful evacuation, fire doors are not a good idea. Yet a firewall cannot be a firewall without a fire door! Thus it is argued that such walls will not be generally helpful with respect to the evacuation of the occupants.

Smoke Control

Why is the need for smoke control related to the size of a compartment? It is probably related to the number of people that may have to be evacuated from a certain area within a building. Ref [1] sees that enclosure size is important as this better reflects the number of people and time that it will take to leave the enclosure. However, smoke control is not seen as necessary unless the plan area of the enclosure exceeds 500m^2. Otherwise, it is important that sufficient egress paths from each area or enclosure remain tenable for the expected duration of evacuation from that area or enclosure. In areas such as concourses, this can often be achieved through natural ventilation. Adequate natural venting is provided in most parts of the Level 2 concourse. In the case of Level 3, particular care is required to ensure that a sufficient number of egress paths can be maintained smoke free as the occupants seek to evacuate the corporate suites or function rooms should a fire develop in these areas.

However, the addition of sprinklers to the building can be assumed to remove the need for any other form of smoke control. This assessment is based on the results of sprinklered fire tests that show that, given a sprinklered fire of the type likely to occur in this building, the occupants are very unlikely to be exposed to threatening smoke.

Top: Eastern Stand, L4 transfer beams.
Above: Fire-fighting equipment at the new stand.

Hydrant Capacity

Based on studies reported in "Fire Safety in Shopping Centres" [Ref 2], it can be inferred that hydrant capacity sufficient to run two hose streams simultaneously at full capacity will be required to successfully fight a fire that has spread to several standard corporate suites, or an equivalent area. Beyond that, additional capacity may be required.

The required hydrant capacity as given in AS2419.1 is related to compartment area. This presupposes two things - that fire size is related to compartment area; and that compartmentation is likely to be effective. The latter assumption has been challenged and the former raises the question as to how extensive a credible fire could become in one of these buildings.[2] If it is decided that the most extensive credible fire in a non-sprinklered building will not go beyond several corporate suites or an equivalent area, then no further capacity is required. If it is decided that a credible fire could extend beyond such a localised area, then additional hydrant capacity must be provided - although if the fire gets large enough, it will be very difficult to fight or control. The addition of sprinklers to the building will allow the hydrant capacity to remain at the lower level.

Flexibility of Construction

According to [1], if the building is sprinklered, then the fire-resistance of the building structure (beams, columns and floor slabs) is not likely to be an issue and this allows for a more flexible choice of protection systems for members (ceilings and column cladding) than would otherwise be possible. Furthermore, the presence of sprinklers will obviate the need for any specific exhaust or venting requirements. Travel distances may also be extended, although exit widths should remain the same.

Sprinkler Protection

It is interesting to note that public buildings such as major stadiums are often sprinklered. This is due to the desire to minimise the likelihood of having a threatening fire, which could have significant political and business implications - due to loss of life or utility. However, the decision as to whether the building should be sprinklered must be made by each owner. In this context, sprinklers should be extra-light hazard and provided in all areas with the exception of toilets, change rooms, gymnasiums and concourses (excluding food and beverage outlets). A booster connection should be provided to allow the fire brigade to pressure boost the system should this be necessary.

Management Issues

The development of management plans for evacuation and fire fighting is important for these grandstands. The management plans should cover such issues as staff training in fire fighting and evacuation and maintenance of fire fighting equipment.

1 *This is considered to be a high estimate as 56 persons died at Bradford, which had no fire-safety features whatsoever and was constructed in such a way that the fire was able to spread rapidly throughout.*

2 *A fire may occur at a time when there are no occupants to detect its presence.*

New Eastern, Western and Southern Stands – the fire-engineered solution

A performance-based design was carried out by OneSteel in conjunction with Norman Disney & Young, the project building and fire services consultant. The BHP publication "Design of Sports Stand Buildings for Fire Safety" was included in the OneSteel submission. After consideration by the consulting team, Watpac, Qld Fire & Rescue Authority and Project Services, the publication was accepted by the approving authority (Project Services) as the Fire Engineering Design Brief (FEDB) for the project. The submission identified the relevant BCA performance requirements and documented how these requirements were satisfied by the FEDB.

The fire-engineered solution resulted in sprinklered construction utilising an unprotected steel frame, with a consequent saving in the cost of passive fire protection to the steel frame of approximately $1.3M. By avoiding compartmentation of the new construction, the overall complex is better integrated, and allows the free movement of people.

Specifically, the following fire safety features are significant in the new construction:

(1) Compartmentation

- There are no fire walls throughout the building

(2) Occupant Avoidance

- The buildings are generally open and all enclosures with a plan dimension of greater than 20m have alternative exits, thereby providing adequate care against entrapment. Exit spacings and widths throughout the buildings comply with the deemed-to-satisfy requirements of the BCA. Travel distances also comply (although this is not necessary in a sprinklered building).
- An Emergency Warning Information System (EWIS) system is not necessary for these buildings. A public address system is required however in order to give instructions to the occupants, but any evacuation must be a staged evacuation with appropriate assistance from ground staff. In the case of persons with mobility disabilities, it is reasonably assumed that if they are within the enclosure of fire origin, their evacuation will be assisted. Once persons are outside the enclosure of fire origin, there is sufficient natural venting and volume for smoke not to present a threat to occupants.

(3) Smoke Control

- All areas are sprinklered in accordance with AS2118, with the exception of concourses, change rooms, toilets and open seating areas. The sprinklers are continued into the existing Northern Stand for a distance of one bay.
- The most potentially critical part of the building with respect to smoke logging, and therefore evacuation, is the corporate level, Level 3. This is because of the relatively narrow passageways that provide access to, and egress from, the corporate suites. Based on BHP sprinklered fire tests, where there has been little shielding and where the water virtually extinguishes the fire, it is likely that the smoke associated with such a fire will be sufficiently dilute so as not to present a threat to occupants outside the enclosure of fire origin.
- Other than the natural ventilation inherent within the proposed design, there is no need for other smoke exhaust systems (eg. mechanical systems) within the buildings.

(4) Fire Detection and Suppression

- Activation of sprinklers will result in a signal to the FIP panel (and therefore to building management) and to the brigade. No further detection is required.
- Portable fire extinguishers, hose reels and hydrants are provided in accordance with [1], and to AS2444, AS2441, and AS2419.1 respectively.

(5) Fire Spread and Management

- The fact that the proposed building is sprinklered means that the likelihood of spread of fire beyond the area or enclosure of fire origin is extremely unlikely. Furthermore, the lack of combustible construction and the fact that many parts of the building are naturally divided into many enclosures will provide additional resistance to the spread of fire.
- The seating tiers for the proposed building incorporate concrete plats such that the spaces below the seating are isolated and there is no possibility of accumulated rubbish being built up.
- Floor slabs and other concrete members will be adequate if an FRL of 60 minutes is achieved. However, in the case of steel beams and columns, maximum exposed surface area to mass ratios (k_{sm}) of 30 and $26m^2$/tonne, for beams and columns respectively, should not be exceeded. The roof and roof support structure, being non-combustible, do not require an FRL in accordance with the concessions provided for open spectator stands in the BCA.

(6) Management / Operations Issues

- The sprinkler system must be properly commissioned, maintained, and managed. A documented procedure is to be developed to ensure that sprinklers are not isolated during a major event and that, should the system need to be isolated, the isolation time will be kept to the absolute minimum.
- Portable extinguishers, hose reels and hydrants must be routinely maintained, with this activity being systematically documented and audited. Procedures and programs are to be subject to audit.
- Documented action plans must be developed in conjunction with Queensland Fire & Rescue Authority to cover the following matters:
  - Evacuation of various parts of the building (eg Level 3) to safer areas should this be required
  - Provision of access to various parts of the building to minimise the time for brigade fire-fighting
  - Evacuation of disabled occupants using lifts, should this be necessary.

OneSteel also carried out an audit of the grandstand construction to ensure compliance of the construction with the intent of the FEDB.

Fabrication & Erection

Beenleigh Steel Fabrications Pty Ltd fabricated and erected all 1,420 tonnes of steel for the project. They also erected a total of 2,303 individual precast concrete seating plats, floor planks and wall panels. Cranage for the Eastern Stand comprised three tower cranes and steel erection proceeded from each end of the stand concurrently. One tower crane was used on the Western Stand. Cranage for the Southern Stand comprised three tower cranes, which were supplemented by one 70T and one 25T mobile crane and erection proceeded from both ends simultaneously. All tower cranes were provided by the builder, Watpac.

The 28m long roof trusses were transported to site in one length, then the support columns and struts were attached on ground before hoisting into final position.

Protective Coating

Three different protective coating systems were adopted, depending on the exposure conditions and the accessibility of the steel for future maintenance. The three systems all had a Class $2^1/_2$ abrasive blast clean and were painted as follows:

Type 1: General steelwork, not exposed

- Zincanode 402 to 75 microns DFT

Type 2: Exposed and accessible steelwork

- Amercoat 385 to 125 microns DFT
- Luxathane RT to 50 microns DFT

Type 3: Exposed and less accessible steelwork (eg roof structure)

- Zincanode 402 to 75 microns DFT
- Amercoat 385 to 125 microns DFT
- Luxathane RT to 50 microns DFT

The BCG Northern Stand is previously described in *Structural Steel Casebook No.13, Nov '96*, which is available from OneSteel Direct (phone 1800-1-78335).

References

1. Bennetts, I.D. et alia (1998), *Design of Sports Stand Buildings for Fire Safety*
2. Bennetts, I.D. et alia (1998), *Fire Safety in Shopping Centres, Final Research Report Project 6, Fire Code Reform Centre*

Grandstand	Steelwork (Tonnes)		Precast Concrete Erection (No. Items)		
	Structurals & Plate	CHS & RHS	Floor Planks	Seating Plats	Wall Panels
18 Bays East	418	141	455 combined	763 combined	154 combined
5 Bays West	161	40			
15 Bays South	508	152	403	406	122
Total	**1087T**	**333T**			

Project Participants

Client:	Brisbane Cricket Ground Trust
Project Manager:	Project and Development Services Pty Ltd
Document & Construct Contractors:	Watpac Australia Pty Ltd
Consulting Architects:	Daryl Jackson Pty Ltd
Consulting Engineer - structural & civil:	Robert Bird & Partners Pty Ltd
Building Services Engineer:	Norman Disney & Young Pty Ltd
Specialist Fire Engineering:	BHP Research (Dr Ian Bennetts)
Hydraulics Engineer	Tom Cooper & Associates
Building Authority:	Project Services, Dept of Public Works
Steel Fabricator & Erector:	Beenleigh Steel Fabrications Pty Ltd
Shop Detailers:	Tregar Engineering Services (St 4) Online Drafting Services (St 5)

FIRE SAFE

New Queensland Cricketers Club, Northern Stand

This Casebook is published by OneSteel. The market development initiatives previously undertaken by BHP Long Products (now OneSteel) will continue with Australia's newest steel company, OneSteel Limited. Further information can be obtained from OneSteel Direct on 1800-1-STEEL (1800-1-78335)

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