Design and Engineering for Fire

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ABSTRACT

The paper sets into an historical context the current community concern about fire safety, and explores how building regulations are developing slowly towards a more flexible format, potentially able to respond to innovative ideas. In contrast, current building Regulations are shown to be frequently ill–suited to controlling unusual buildings such as as fabric structures, and examples are given of how an analysis from first principles can be useful in resolving fire safety and regulatory problems.

1. INTRODUCTION

Technology and computer–aided design are widening the horizons for unusual buildings such as those using innovative lightweight structural forms. At the same time, the community is becoming more concerned about fire safety, and building regulations are becoming correspondingly more complex. This tends to restrict some potential advances from being transformed into reality.

The rising discipline of professional fire engineering, however, is providing better tools and people to analyse the real fire safety problems and assist in smoothing the transformation of unusual architectural ideas into realities to enhance our environment, despite the constraints of building regulations.

2. HISTORICAL PERSPECTIVE

History is scattered with fire tragedies such as the burning of Rome (64 AD), the Great Fire of London (1666, with 100,000 homeless), the Chicago theatre fire (1903 – 602 deaths), and the Brussels department store fire (1967 – 325 deaths). Australia's greatest fire tragedy is its regularly recurring bush fires e.g. 'Ash Wednesday' (1983 – 74 deaths).

So far, apparently, no major fire has occurred in a lightweight structure. But the fear remains as always, and is exacerbated by the knowledge that a fire in a tension, fabric or inflatable structure would probably result in unusual structural behaviour. This fear of fire has grown over the past three decades as the world has witnessed massive fire tragedies, even in new buildings, and wondered why modern technology cannot do better.

Fires such as those at Sao Paulo (1972 – 16 dead), the MGM Hotel in Las Vegas (1980 – 85 dead), and the Isle of Man Summerland Leisure Centre (1973 – 50 dead) have lead to disaster movies such as The Towering Inferno (1975).

Television camera crews can arrive at a fire scene at the peak of the excitement, and advertisers know that home viewers love to watch fires.

The result is that fire safety is now a public issue – not a high level issue, perhaps, but higher than it was in, say, 1963.

In that year Robin Boyd, the noted Australian architect, wrote 'Under Tension' – a world wide review of tensile structures. In this he wrote '... in practice, tension is thwarted in many kinds of buildings, by the requirements of fireproofing'.

In this same review, however Boyd discussed two major Australian tensile structures engineered by Bill Irwin, in neither of which fire considerations affected the design:

- the 1956 Melbourne Olympic Swimming Pool, and
- the 1958 Melbourne Myer Music Bowl.

The fire aspects of these are discussed below.

In the same review, Boyd predicted that '... the extra complexities introduced by all the new structural methods are ... likely to increase the number of separate building specialists'. How right he was. As a result of increasing public concern with fire safety, and even more complex fire regulations, and as a result of advancing technological understanding, there has arisen the new engineering discipline of fire engineering, as discussed below.

3. BUILDING REGULATIONS: ILL FITTED FOR UNUSUAL BUILDINGS

Building regulations endeavour to set the parameters within which a design team can work to achieve a total design compromise which will achieve that optimum investment in fire safety compromise which society expects: the compromise between cost and safety. However, the issues are so complex that inevitably the regulations fail to cater for every case. Equally inevitably, they fail most badly in the cases of unusual buildings, which had not been in the minds of the authors of the regulations; and unusual buildings, of course, include lightweight structures such as inflatable buildings and fabric roofs.

Regulations also fail because they cannot keep up with technical advances in the understanding of fire.

Building Regulations are traditionally controlled as much by questions of 'how can we enforce this?' as by more fundamental ones such as 'does this particular combination of measures provide adequate fire safety for this particular building, given its particular usage and clientele?'

The traditional approach of crudely mandatory regulations is gradually giving way in the Building Code of Australia to a slightly more flexible approach. This embraces the concept of a 'performance requirement' (which sets a standard to be achieved) coupled with a 'deemed to satisfy' measure. However, there are problems with this approach, including the following:

(d) Hardly any of the performance requirements are currently expressed in quantifiable terms.

(e) Who is permitted to use their discretion and rely upon the apparent flexibility of the performance requirement rather than the certainty of the deemed to satisfy?

(f) This approach does not provide any flexibility for trade–offs between topics. (There is no overall performance requirement for the BCA as a whole.)

It is mainly in the areas where the Building Regulations 'fail' that professional fire engineers have a role to play, and most regulatory systems have a route for dealing with special cases. So, if a lightweight structure proposal is liable to rejection by virtue of fire–related provisions within the regulatory system, than a professional fire engineer should be able to assist in steering the project through the 'special case' system, by addressing the legitimate concerns of regulatory officials, by providing the necessary documentation and expert opinion, and by forging compromise and concensus where appropriate.

4. FIRE SAFETY IS MORE THAN FIRE RATED STRUCTURE AND SQUIRTING WATER

The 'total fire safety of a building' is a concept which combines the impact of many fire safety features. One way of analysing some of the key concepts is shown in the figure. However, the 'total safety' concept fails to define the objectives of fire safety for any particular building. For example, is it adequate to provide a reasonable degree of fire safety for people, but not be significantly concerned to save the building?

A lightweight structure cannot, in practice, be provided with a formal fire resistance rating. Therefore, when proposing a lightweight structure, it is useful to analyse from fundamentals (rather than just from the regulations) why the particular structure might or might not need a fire resistance.

It may be possible to dispense with a fire resistance rating required by regulation – perhaps by offering some other combination of fire safety features, some of which may not be required by regulation.

A similar situation may occur with a requirement for a roof to be 'non–combustible', which effectively prohibits the use of any fabric for the roof. Upon analysis, it may be found that there are some advantages if the roof were to catch alight early in the course of a fire, and thereby release the smoke and allow people to see the escape routes and the fire brigade to fight the fire more easily. Perhaps these advantages might outweigh the more obvious disadvantages posed by a burning roof: its ability, probably, to spread the fire, and the probability that it will collapse.

5. PROFESSIONAL FIRE ENGINEERING: UNDERSTANDING THE PHENOMENON FOR FIRE

Man has always researched fire.

- In 1884 the first effective automatic sprinkler system was installed.
- In 1917 the international time–temperature test curve was devised.
- In the second world war, observations of burning buildings led to a better understanding of structural resistance to fire.
- In 1945 the State of Victoria introduced Uniform Building Regulations, largely concerned with fire.
- The importance of the 'fire load' of building contents was recognised from the start of modern building regulations; but the

importance of early fire hazard properties of materials was only addressed in Australia with the publication of a testing code in 1945.

- In 1972 the quantitative theory of how ventilation affects fires in buildings was derived from a massive international testing effort.
- In 1976 an Australian Code concerned with smoke control in buildings was published.
- In 1989 Australia led the world with a combined effort on the part of all sectors of the building design, construction, regulation and safety industry. The 'Fire Safety and Engineering' project, led by Professor Vaughan Beck, at the Warren Centre at the University of New South Wales. By showing that fire safety can be designed on a rational, probabilistic basis, it was a massive symbolic step forward which has led to further substantial federally funded research to develop a new rational fire design code for buildings. A senior Canadian observer, Kenneth Richardson, has predicted that Canada will follow 'because it does not want the International Monetary Fund to take over the country'. In other words, he sees that countries without such potentially cost–saving building codes will find it even harder to compete for the investment dollar in the world wide competitive market place.

Clearly, fire engineering is now far wider than devising better ways for fire fighters to courageously squirt water at fires. The professional fire engineer, by analysing the real issues of a particular building project, can help the design team to reach a cost effective total design compromise. His work may embrace a resolution of what the proper objectives and performance requirements should be, as well as the more technological question of how to achieve them.

Some examples of lightweight structures and their fire–related provisions are below, taken from the experience of the author's firm.

6. CONVERTING THE 1956 MELBOURNE OLYMPIC POOL INTO A SPORTS AND ENTERTAINMENT CENTRE.

In 1956 the swimming events of the Melbourne Olympic Games were held in a dramatic, innovative pool building with a lightweight post–tensioned steel truss roof forming part of an articulated structure. This was described by Boyd as 'an exemplary 2–D tension design', devised by architects Kevin Borland, Peter McIntyre and John and Phyllis Murphy and, especially, engineer Bill Irwin. Not surprisingly, the building is now listed by the National Trust.

A quarter of a century later, architect Bernard Brown converted this unique building into the Melbourne Sports and Entertainment Centre and provided this author, as part of the Irwin Johnston integrated engineering team, with the opportunity to devise a rational, radical fire protection strategy from fundamentals, using regulations as a guide but not a straight–jacket.

The fire safety strategy which broke many normal regulatory requirements is described in some detail in Architectural Science Review Volume 27 No. 1, and included such features as:

- great care with flammability characteristics of the carpets and seats;

- sprinklers generally, but not over the majority of the auditorium;
- smoke resistant doors that close when smoke is detected, thus forming evacuation routes protected from smoke; and
- emergency communications.

This chance for innovation only arose because the state government was not strictly bound by the regulations, and the strategy was only accepted because the government was convinced of the difficulty of imposing modern regulatory solutions on this unique building; and also convinced of the soundness of the fire strategy – despite its heretically radical nature.

7. MYER MUSIC BOWL, MELBOURNE

Architects Yuncken Freeman and Associates, together with engineers Bill Irwin and Roy Johnston, richly deserved the awards they received for their famous 1958 Myer Music Bowl in The Domain gardens in Melbourne.

Here, surely, is a structure that is not catered for by building regulations, and yet under one interpretation of the regulations, its roof would have to have a fire resistance rating of one hour. In contrast, the shell structure actually comprises aluminium–faced plywood panels fastened to exposed steel cables!

Neither architect nor engineer can recall fire being a design consideration at all, and its only fire protection is a couple of hydrants.

8. CHADSTONE SHOPPING CENTRE, MELBOURNE

When the Chadstone Shopping Centre, in suburban Melbourne, was renovated and extended, architects Buchan, Laird and Bawden Pty Ltd chose an arched fabric roof over the main shopping mall.

The redevelopment proposals involved many modifications to the Building Regulations, and it was clearly important to get the broad support of the fire brigade, irrespective of any direct regulatory requirement for any particular item. Their concerns covered many traditional matters such as means of egress, smoke control, fire compartmentation and sprinkler protection throughout.

They were also concerned with the proposals for a fabric roof: Would it burn? Would it spread fire rapidly? Would it collapse in a fire situation? Could it be cut by firemen to improve the release of smoke? How would the mall beneath by sprinkler protected?

In the end, the concerns were resolved. Test certificates showed suitably low early fire hazard indices. A sample of the fabric was attacked by a fireman with an axe and found to be cuttable. The Insurance Council of Australia was cautious about the idea of the tubular steel arch roof supports also acting as sprinkler pipes. However, possible union demarcation problems on that same question were solved when the arch fabrication contract was won by a plumbing company!

The end result was that, as a result of a team effort and good will, the extensions went ahead, and the fabric roof is a triumph. It is supported by water filled arch tubes which would perform admirably in a fire, and which also act as huge sprinkler pipes.

9. REDEVELOPMENT PROPOSALS FOR WALSH BAY, SYDNEY

The 1989 proposals to redevelop the disused wharves of Walsh Bay as an hotel and as apartments created a challenge for the design team, and for the regulatory control team. There was a political will for the project to happen. Yet, how could anyone countenance a timber structure, impregnated with decades of wool grease, in lieu of the concrete demanded by the regulations?

How could we treat the pier space around the building as an 'open space' when considering egress?

The answers lay in a patient consideration of the real issues, and a steady approach to addressing them; followed by a very patient exposition of the rational, yet radical, proposals to the regulatory authorities. And coupled to this was an interdisciplinary approach to detailing:

- could acoustic separation enhance the containment of fire and smoke, and vice versa?
- could wiring for smoke detectors in flats also be used for everyday security systems?
- could lightweight fire resistant construction be beneficial in avoiding structural upgrading and, also, be cheaper to construct? Could the authorities accept it in lieu of the 'concrete or masonry' demanded by the authorities?
- could arguments concerning everyday practicalities of traffic circulation also hold sway in evaluating egress strategies?
- could computer analyses of smoke spread also provide insights into how the operation of everyday air handling systems could be enhanced?

In every case, the answer was yes: The technical solutions were a series of triumphs; the sadness was that the financial bubble of the 1980s burst before they could be put into effect.

10. CONCLUDING COMMENTS

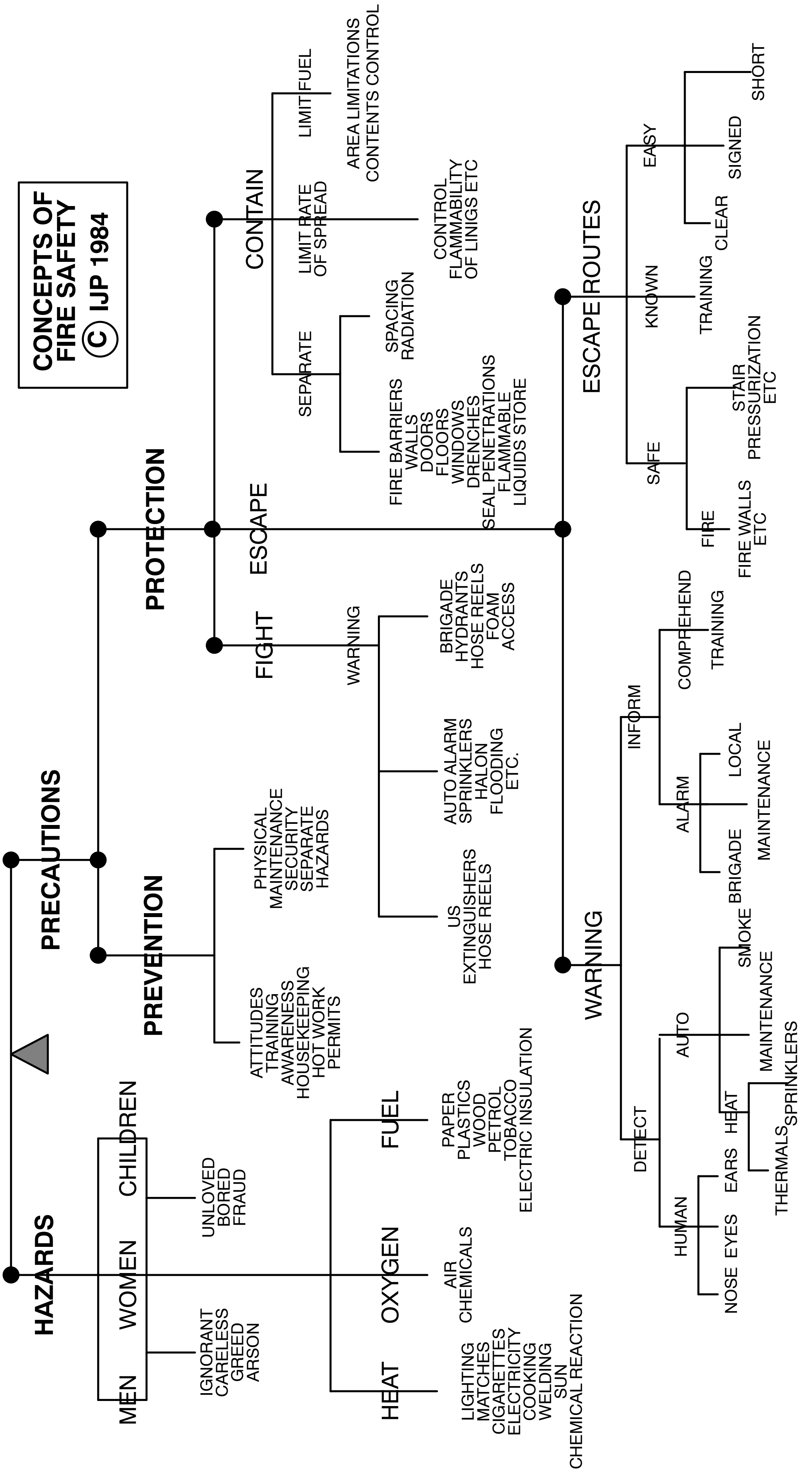
Fire will always be an emotive topic. Conservatism in respect of fire safety will always be a potent force in the thinking of fire brigades and regulatory authorities. These factors will always tend to be exacerbated in any case of an unusual building, such as a lightweight structure. However, fire issues can be analysed rationally and the new discipline of fire engineering can provide assistance in preventing conservatism from blindly resisting such innovative advances as fabric and lightweight structures.

Melbourne Sports and Entertainment Centre.

NOTE: Sprinkler system incorporated into structural arch members

Chadstone Shopping Centre, Melbourne
(Note sprinkler visible in main cross arches near seams in fabric roof)

1989 Proposals for Walsh Bay, Sydney


CONCEPTS OF FIRE SAFETY
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HAZARDS
MEN
WOMEN
CHILDREN
IGNORANT CARELESS GREED ARSON
UNLOVED BORED FRAUD
HEAT
OXYGEN
FUEL
LIGHTING MATCHES CIGARETTES ELECTRICITY COOKING WELDING SUN CHEMICAL REACTION
AIR CHEMICALS
PAPER PLASTICS WOOD PETROL TOBACCO ELECTRIC INSULATION
PRECAUTIONS
PREVENTION
ATTITUDES TRAINING AWARENESS HOUSEKEEPING HOT WORK PERMITS
PHYSICAL MAINTENANCE SECURITY SEPARATE HAZARDS
PROTECTION
FIGHT
WARNING
US EXTINGUISHERS HOSE REELS
AUTO ALARM SPRINKLERS HALON FLOODING ETC.
BRIGADE HYDRANTS HOSE REELS FOAM ACCESS
ESCAPE
CONTAIN
SEPARATE
FIRE BARRIERS WALLS DOORS FLOORS WINDOWS DRENCHES SEAL PENETRATIONS FLAMMABLE LIQUIDS STORE
SPACING RADIATION
LIMIT RATE OF SPREAD
CONTROL FLAMMABILITY OF LINIGS ETC
LIMIT FUEL
AREA LIMITATIONS CONTENTS CONTROL
WARNING
DETECT
HUMAN
NOSE EYES EARS
HEAT
THERMALS SPRINKLERS
AUTO
SMOKE
MAINTENANCE
INFORM
ALARM
BRIGADE
LOCAL
MAINTENANCE
COMPREHEND
TRAINING
ESCAPE ROUTES
SAFE
FIRE
FIRE WALLS ETC
STAIR PRESSURIZATION ETC
KNOWN
TRAINING
EASY
CLEAR
SIGNED
SHORT