STUDY REPORT

No. SR 128 (2004)

Fire Protection of New Zealand's Traditional Māori Buildings

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Preface

Research investigating fire protection for New Zealand's traditional Māori buildings was conducted by BRANZ and the New Zealand Historic Places Trust.

There is a lack of scientific data on the fire properties and fire growth characteristics of some traditional natural materials used to line the walls and ceilings of wharenui, or meeting houses. One of the objectives of this study was to measure the important fire properties of these natural materials.

Information from the full-scale testing was used in conjunction with computer modelling to simulate fire behaviour in larger buildings, such as wharenui.

Recommendations have been made regarding fire protection measures and building regulations for this type of building.

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The New Zealand Historic Places Trust for work in kind.

The New Zealand Fire Service for contributions in kind.

Mark Wilson, Sam Cook and Iwi Cook, builders of replica traditional wall and ceiling lining construction.

Raukawa Marae Trustees – permission to use photographs and the use of Raukawa Marae, Otaki as a case study.

Note

This report is intended for fire engineers, architects, designers, codewriters and other researchers into fire safety of traditional Māori buildings.

FIRE PROTECTION OF NEW ZEALAND’S TRADITIONAL MĀORI BUILDINGS

BRANZ Study Report SR 128
C. R. Duncan, P. Whiting, C. A. Wade, D. Whiting & A. Henderson

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KEY WORDS

Fire safety, fire protection, occupant life safety, Māori buildings, marae, wharenui, fire properties of traditional Māori construction materials, full-scale room fire test, small-scale fire tests, computer fire modelling, building controls.

ABSTRACT

A significant part of Māori heritage is contained within the fabric of marae buildings, and in particular the wharenui or meeting house. The interior of these wharenui are typically decorated with ornate timber carvings, painted artwork and woven panels that provide the present generation with links to their ancestors. In addition, many marae also contain taonga (treasured photos, paintings and objects) belonging to the hapu and iwi.

Over the years many of these Māori buildings have been damaged by fire, some beyond repair. Their loss is a local tragedy as well as a national one.

The research objective was to investigate the issue of fire protection for New Zealand’s traditional Māori buildings.

The incidence of fires in Māori buildings was investigated via the New Zealand Fire Service Fire Incident Reporting System records to determine the scale of the problem. In addition, fire protection approaches developed for historic buildings in general were studied for relevance to Māori buildings, including the use of active and passive systems (sprinklers and fire retardant treatments).

There is a lack of scientific data on the fire properties and fire growth characteristics of some traditional, natural materials used to line the walls and ceilings of the wharenui. The aim of this experimental series was to measure the important fire properties of these natural materials using the BRANZ fire laboratory small-scale and full-scale facilities.

The BRANZfire computer model utilised the fire test data to validate the modelling inputs. BRANZfire was used to model a full-size wharenui to predict the fire development and tenability conditions that may exist in a real fire scenario. Evacuation modelling was carried out to assess the efficiency of the egress system and compared with the time to untenable conditions.

The research concluded that the existing NZBC Acceptable Solution provisions for wharenui result in a reduced level of life safety when benchmarked against an equivalent building with complying wall and ceiling linings. It also highlighted the need for an efficient early fire-detection and warning system to be installed, for example smoke detection. This does not offer any fire protection of the building fabric and so additional measures are considered for the limitation of fire damage to these heritage buildings.

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1. Executive summary

1.1 Introduction

This report investigates the fire safety and fire properties of New Zealand's traditional Māori buildings and the suitability of the present building controls, in particular the 'special case' provisions relating to wharenui in the New Zealand Building Code (NZBC) Acceptable Solutions (BIA, 2001). The 'special case' provisions apply only to wharenui where traditional surface finishes do not meet current flammability and smoke development criteria. This is compensated for by requiring exit widths to be doubled and open path lengths to be halved. This report concentrates on wharenui as these are used to provide sleeping accommodation and therefore attract more stringent fire-related building controls.

The report includes an introduction to the various types of traditional Māori buildings, their construction methods and materials used, and the incidences of reported fires in marae buildings from records collected by the New Zealand Fire Service (NZFS). The effectiveness of fire safety education within Māori communities, the ability of the NZFS to respond to a building fire on a marae, and the charter, which is the basis for the preservation of historically significant buildings in New Zealand, are discussed. Several buildings are case studied, and relevant building code provisions from New Zealand, the United States of America and Australia reviewed. The research for this report included full-scale and small-scale fire tests, and the results from these were used to characterise the fire performance of traditional Māori wharenui. Computer fire modelling, based on the results from the fire testing together with evacuation analysis, highlights discrepancies in the level of fire safety afforded by the present 'special case' provisions. Recommendations for changes to the NZBC Acceptable Solutions (BIA, 2001) are made with a proposal for an alternative approach to the control of interior surface finishes.

1.2 Traditional Māori buildings

The wharenui represents a tribal ancestry as a living entity through its design, construction and decoration. It is a genealogical map that ties the descendent people together, relating to the past through the representation of ancestral figures.

There are three main phases of Māori construction; the methods and materials change depending on the degree of contact with and influence from European settlers. These phases are identified as the Early Contact phase from 1769 to 1860, the Late Contact phase from 1860 to 1900, and the Modern phase from 1900 to present.

Four key components of a wharenui were used in the evaluation of the overall fire performance, totara (used in the major carvings), rimu (used extensively in construction), tukutuku wall panels (decorative wall lining panels), and toetoe (used extensively in ceilings and in backing to tukutuku panels).

1.3 Statistics and fire safety education

The incidence of fires in marae wharenui is not well recorded by the NZFS Fire Incident Reporting Management System (FIRMS). There have been many incidents of fires occurring, but the database is not specific as to which of the marae buildings were involved.

A study into the fire safety education of Māori concluded that the marae would be the most effective location for its delivery, and that it would be viable to introduce bilingual, Māori and English language fire safety signs for use within the traditional building environment.

The study indicated that there was a need for continued education in fire safety awareness and that included the use, effectiveness and maintenance of smoke alarms.

1.4 New Zealand Fire Service intervention

In the event of a structural building fire on marae, the Fire Service is rarely able to save the building of fire origin from sustaining major damage, often only preventing the fire from spreading to neighbouring buildings. There are many factors that contribute to this, including the fact that many marae are remote, with limited fire-fighting water supplies, and are often unoccupied and without automatic fire detection systems. Some examples taken from the Rotorua area illustrate that the Fire Service response time to marae can vary enormously to the point where total loss is the only expected outcome.

1.5 Fire safety of buildings legislation

The two main pieces of legislation that deal with the fire safety of buildings are the Building Act 1991 (New Zealand Government, 1991 No. 150), and the Fire Service Act 1975 (New Zealand Government, 1975 No. 42). The Building Act is applicable to existing buildings if the building is undergoing alteration, and/or if the building use is being changed. Varying degrees of compliance are specified. The Fire Service Act requires specific buildings, including heritage buildings that are used by the public, to have an evacuation scheme. Approval of the scheme is required if the building does not have an approved fire sprinkler system.

1.6 Protection and preservation of historic buildings

The International Council on Monuments and Sites (ICOMOS) New Zealand charter (ICOMOS, 1993), defines that the purpose of conservation is to care for the places of cultural heritage value, their structures, materials and cultural meaning. This charter has specific inclusions for the protection and preservation of Māori buildings, and forms the operational guidelines of the New Zealand Historic Places Trust in the conservation of these buildings.

The New Zealand Historic Places Trust has published a set of fire safety guidelines specifically aimed at improving the fire safety of heritage buildings without compromising their heritage, character or value. Included is guidance on the assessment of heritage significance, development of fire safety objectives, conducting risk assessment, meeting the Building Code requirements, and identification and evaluation of fire safety options.

1.7 Case studies

Four buildings are case studied. Two are included to illustrate the diversity of building styles: the wharenui at Raukawa Marae, a traditional-style building lined with traditional materials and decoration, and Tapu Te Ranga, representing a more contemporary design approach with the use of recycled materials reinforcing the idea of sustainable living. Hinerupe Wharenui is included to highlight the extent of a potential loss where fire safety has not been considered. St Mary's Church is an example of recognising the cultural significance of a building leading to the inclusion of fire safety in the conservation plan and subsequent renovations.

1.8 Building Code regulations

Internationally there are many differing approaches to the fire safety regulation and preservation of heritage buildings such as wharenui. To illustrate this, the specific requirements in the NZBC Acceptable Solutions are detailed, together with two National Fire Protection Association (NFPA) codes in the US and deemed to satisfy requirements of the Building Code of Australia. Both the New Zealand and Australian approaches are similar in terms of concentrating on the safety of the occupants, and only concerned with preventing damage to, or loss of, neighbouring property. The test methods used for the regulation of interior wall and ceiling linings in the Australian code have recently been modified and are now based on more realistic fire testing than that currently used for compliance with the NZBC Acceptable Solutions. The two NFPA codes split the preservation and life safety concerns; NFPA 909 applies to the preservation of culturally significant structures and their contents, and NFPA 914 covers the fire safety requirements for the protection of historic structures and for those who operate, use or visit them.

1.9 Experimental work

The experimental phase comprised full-scale and small-scale testing. The full-scale test provided key information on the expected real fire performance of a wharenui constructed in the traditional manner, and materials. The small-scale tests were conducted to provide detailed fire performance property data for each of the main materials and components used in traditional wharenui.

The full-scale test was conducted in the BRANZ ISO 9705 test facility in accordance with ISO 9705 for full-scale room testing. The ISO 9705 test room measures 2.4 m x 3.6 m in plan by 2.4 m high, and with a 0.8 m x 2.0 m door in the centre of one of the short-end walls. The test comprised a mock-up of a traditionally built wharenui using full-sized timbers and wall and ceiling lining materials.

The small-scale tests were conducted on the BRANZ Cone Calorimeter in accordance with AS/NZS 3837. The major interior components of a wharenui, namely totara (carvings), rimu (construction), tukutuku wall panels (decorative wall panels), and toetoe (use in the tukutuku panels and in ceiling linings) were tested separately. The tests on each component were conducted at a range of irradiance levels to enable their reaction to fire to be characterised.

1.10 Computer modelling

The purpose of the computer modelling was to enable fire development and tenability conditions to be predicted within wharenui of a much larger scale than that tested in the ISO9705 test facility. The BRANZfire computer model was used to make full-scale fire predictions based on the performance data recorded in the small-scale series of fire tests. The ability of the computer model to predict wharenui fire performance was illustrated by accurately reproducing the full-scale ISO 9705 fire test results. The computer model was then used to predict the fire development and tenability conditions within a full-size wharenui, using both the ISO 9705 gas burner and a realistic mattress fire as the primary ignition sources. For comparative purposes, two further buildings were modelled. The first was a wharenui complying with all provisions in the NZBC Acceptable Solutions, and the second was a conventional building of equivalent dimensions with fully NZBC-compliant wall and ceiling linings.

Evacuation modelling was then done to assess the effectiveness of each building design, including the NZBC Acceptable Solution requirements for the number and width of exits. The available safe egress time (ASET) for each scenario modelled was taken from the BRANZfire tenability predictions. The evacuation analysis findings indicate that:

- a single exit door may not provide adequate egress from a wharenui
- two standard-width exits may provide adequate egress capacity, albeit without any margin for safety
- two double-width exits (in accordance with NZBC Acceptable Solutions) offers an improvement over two standard width exit doors

- the alternative provisions in the NZBC Acceptable Solutions for wharenui result in a reduced level of fire safety for the building occupants than would be achieved in a fully compliant conventional building.

1.11 Building control implications

The results of the experiments and modelling lead to the conclusion that the NZBC Acceptable Solutions ‘special case’ provisions for wharenui do not fully compensate for the more flammable characteristics of the surface linings used, and the level of life safety provided is lower compared with an alternative compliant building.

It is suggested that although some concessions and relaxation of the surface linings can be justified given improved access to an exit, it is not appropriate to allow ceilings to be constructed of highly flammable materials in spaces where significant numbers of people congregate and sleep.

A possible approach to how the NZBC Acceptable Solutions might deal with the issue of surface finishes in wharenui is presented, including under what circumstances sprinklers ought to be required if untreated/unmodified materials are to be specified for the surface linings. The suggested approach makes use of an alternative classification scheme for surface linings recently introduced to the Building Code of Australia in Amendment 13.

1.12 Recommendations

In addition to recommending changes to the NZBC Acceptable Solutions, further recommendations are included relating to life safety, property protection and preservation of cultural heritage.

The recommendations relating to life safety include the addition of a second exit where there is only one exit; ensuring that all exits have adequate signage; preparation of a fire safety action plan and a practised escape plan; introduction of fire safety management practices and installation of automatic fire alarms, such as smoke detection, in areas used as sleeping accommodation.

The property protection recommendations discuss a range of potential options, from a standard sprinkler system to the application of fire-retardant compounds or intumescent paints, or simply installing an automatic monitoring system to provide the earliest possible notification of a fire to the Fire Service. Preparation should also include local Fire Service involvement for familiarisation, and adoption of good management practices across the entire site to limit the accumulation of potential fuel sources.

To ensure preservation of the cultural heritage, fire safety features should be installed as sympathetically as possible, and the historical significance of these heritage structures should be formally documented.

2. Introduction

This research investigates the fire protection of New Zealand's traditional Māori buildings. The research is not only applicable to existing indigenous buildings but also to new construction where regulatory requirements need to be met alongside the traditional building and cultural aspects.

The research collects information relating to the incidence of fire in indigenous and historic buildings and looks particularly at case studies of Fire Service response and where building location influences the appropriateness of fire protection solutions.

An understanding of the cultural aspects regarding the use, construction and status of Māori buildings is necessary to develop appropriate fire protection systems. Traditional Māori buildings are characterised and building designs are described with regard to their influence on fire protection systems.

A series of small-scale tests and a full-scale experiment were done to collect data on the fire behaviour of typical construction and decorative materials fixed to the interior walls and ceilings. This data is presented and a discussion provided on its applicability to current NZBC requirements. Particular regard is given to the heat release rate (HRR) contributions made by the materials of construction.

The experimental data, statistics and case studies can be used to develop case-specific practical and economic fire protection solutions for traditional Māori buildings.

3. Traditional Māori buildings

In describing the construction types and materials used in wharenui construction it is important to emphasise the cultural values associated with these structures. For the purposes of this research work, the term 'traditional Māori buildings' has been limited to wharenui constructions, those that are used for sleeping, and contain natural materials, such as toetoe, kiekie and raupo.

The wharenui represents a tribal ancestry as a living entity through its design, construction, and decoration. When you enter a wharenui you are entering the embrace and body of the tribe's founding ancestor, or *tupuna*. The carved *koruru* figure at the apex of the roof is the face, and the large bargeboards on each side the outstretched arms. The interior walls are often adorned with ancestral figures that are carved, woven or painted. These connect to the main wharenui ancestors through the *heke* (rafters) and *tahuhu* (ridge beam). The *tahuhu* is the most sacred part of the wharenui and represents the backbone of the ancestor. Residing within it is the *mauri*, or the life spirit that binds the people and the building together. The wharenui is a powerful genealogical map that ties the descendant people together as tribal, sub-tribal or family groups and relates to the past through the representation of ancestral figures.

Wharenui also interact with the Māori spiritual realm and are considered the medium where *Ranginui* (Sky Father) and *Papatuanuku* (Earth Mother) touch one another. Wharenui are often referred to representing *Tane* (God of the Forest) since they are built from trees, the children of *Tane*, and physically stand between the Sky Father and Earth Mother. This is illustrated on some wharenui by the absence of roof guttering to allow the tears (rain) of *Ranginui* to fall on to *Papatuanuku*. This personification of structure and relationship with atua permeates throughout all the elements of the building.

With the arrival of Christianity new religious movements started based on variants of Christian faith and Māori traditional belief, and brought a new order to Māori society that did not rely solely on tribal genealogy for membership. Ringatu, Paimarie, Ratana and Kingitanga movements were some of the many political/religious movements that developed in the late 19th and early 20th century. This change in social structure led to the rapid creation of new artforms and wharenui styles to support the many and varied needs of these new groupings. The highly structured and ritualised artforms, such as carving, gave way in some areas to more collectively produced artforms, such as tukutuku and painted artwork.

Other structures on the marae also evolved. The *wharekai* or dining halls developed to mananki or host visitors to the marae; *pataka* (food store) a rarer structure, traditionally used to hold important marae resources, were gradually displaced, and *whare mate* used in funeral ceremonies to separate the sacred rituals associated with death.

Today there are more than 1000 marae in active use, most of which contain wharenui and associated support buildings. Marae are still being built today, or redeveloped to support the needs of the many individual sub-tribes (*hapu)*. Generally, each marae represents a sub-tribe unit of between 100 and 2000 people. There are other marae, which service the requirements of the whole tribe (*iwi*) and are often much larger buildings. Marae land on which wharenui stand is usually designated as a Māori reservation, a piece of land set aside by the tribe for the purposes of a marae. Trustees are appointed by the Māori Land Court to administer and represent the interests of the wider hapu in the affairs of the marae.

3.1 Construction variations

In describing the variations in wharenui construction styles we have to be aware that existing wharenui are often a result of many years of adaptation and renewal: the structure could be a blend of older construction elements that have been incorporated into a new structure. These are living structures that change with time to be relevant and functional. The following descriptions are not definitive as there are many regional variations that are beyond the scope of this report. The important elements that we are interested in characterising include the interior linings and decorative elements that have become widespread in use but vary in application.

3.1.1 Early Contact phase 1769 - 1890

Pre-European approaches to construction were based on the cantilever construction method where wall slabs (poupou) were partially buried in the ground to provide both the wall upright and foundation. Floors were dug into the ground to take advantage of the insulating qualities of the earth and allow a lower wall height on the exterior. Heke, or rafters, interlocked with the poupou and rested on the tahuhu (ridge beam). The tahuhu was the first member of the building to be positioned. This piece was supported at the ends by large end-wall uprights, poutuarongo and poutahu, and centre post, poutokomanawa, and porch post pou-aro. The tahuhu was the most important structural element and the largest single timber piece within a wharenui. During intertribal musket wars (1820-40) there was widespread destruction of storage and meeting houses. These were often replaced with modified European structures. Māori-built mission churches were also a feature on the landscape in many areas as Christianity influenced Māori society.

Very few original structures of this nature exist. However, many early structures, carvings and interior artwork are now supported by a second skin of timber framing, cladding and iron roofing. Structures often still contain a raupo insulation layer and new floors have been added for comfort.

3.1.2 Late Contact phase 1860 - 1900

This style of construction was on a modest scale until European influences were adapted to produce much larger buildings. This traditional construction approach continued into the late 19th century in many areas. However, there were new buildings being constructed with timber framing methods and those that were a mixture of the new and the old. New Māori religious movements created a transformation in construction intensity and size. Arts changed in many areas to embrace painted expressions of tribal and religious identity, particularly painted artwork. Significant structures, such as Pai Marie temple in the King Country, Ringatu wharenui Rongopai at Waituhi, and townships such as Parihaka, Taranaki, continued to be built using traditional building materials. Often these were incorporated into European construction design. Earth floors began to be replaced with timber floors and older structures were incorporated into timber-framed shells to protect and support the buildings. Traditional insulation materials such as raupo were still incorporated into the structures. Metal fasteners and machined timber was in common use, along with glass windows and flooring materials and commercial paints.

A great many of these houses are in existence even in original construction. There is a wide variety of styles and construction methods from the hall type buildings of Ngapuhi and Ngai Tahu to the traditional forms of wharenui in the Mataatua, Te Taitokerau, Te Arawa and Waikato districts.

3.1.3 Modern phase 1900 to present

Between the 1920s and the 1950s there was a resurgence and revitalisation of wharenui building and traditional arts through the initiation and direction of Sir Apirana Ngata. His drive to strengthen tribal identity and economic independence led to the creation of the Rotorua Māori Arts and Crafts Institute in 1927 to capture the remaining traditional knowledge of the arts and re-teach it to a new generation. This was part of a programme of building new wharenui around the country, and created a distinctive style of building based on contemporary construction at the time. These were characterised by their large size, concrete foundation walls, steel roof ridges, incorporation of stages and high quality of construction. Designed for the modern age, marae included ablution blocks, wharekai (dining halls) with integrated kitchens, and carparks for vehicles. The latter half of the 20th century saw the development of the marae complex, with interlinked buildings incorporating administration buildings, kohanga reo and adjacent kaumatua housing. The use of traditional materials slowly declined as new materials took favour. The use of toetoe in ceiling spaces and tukutuku declined as readily available fluted board was substituted. Native timber use declined as timber became scarce and more expensive. Pinus Radiata became the most common construction timber.

3.2 Applied arts and materials

3.2.1 Carving

Carving was one of the most revered arts applied to wharenui construction, with a strong traditional basis. Carving had evolved during the classical period of Māori society pre-European contact. Subsequent developments were in size, change from stone-based tools to metal, and style. Later there was a shift from flat chisel types to gouges and V-chisel profiles. Earlier carvings provided the structural support to the building and were carved from large sections of timber

Most carvings have been carved from native timbers for their superior working qualities. Preparing timber for carving and construction use was a difficult and time-consuming process when only hand tools were available. A timber that worked easily and was able to be chiselled without tearing across the grain was more favourable than other timber types. Resistance to decay and insect attack were also important features considered in timber selection. However, late in the 19th and into the 20th century the availability of native timber declined and led in some areas to the use of more sapwood and inferior cuts of logs. In some cases timber was substituted for other materials, painted artwork, even concrete casts of carvings in a couple of instances. The following timber types were utilised in construction and carving timber.

Totara (*Podocarpus totara*)

A native pine (soft wood) found growing in sub-alpine regions down to sea level on both islands. Freshly cut material has a distinctive red-brown appearance that fades to yellow-brown over time. It has a natural fungitoxin component, *totarol*, that resists decay and insect attack in the heart timber. It has excellent carving properties and is the most dominant timber used in carving wharenui and in the construction of Early and Contact phase buildings. Heartwood cuts well and the chips break freely away from the timber. Sharp edges in the cross grain can be cut with little tearing.

Kauri (*Agathis australis*)

Another native pine (soft wood) found throughout the upper North Island. It has a light yellow colouration and is very straight-grained. Also has low resistance to decay and insect attack. Is easily worked with good carving properties. Limited use on wharenui, used more as a construction timber in Northland wharenui.

Matai (*Podocarpus spicatus*)

Part of the Podorcapus family of soft woods found in low-land forests in both islands. Possibly carved when green, the timber becomes very hard when seasoned. Used in flooring for its durable surface and widely used in construction. Susceptible to decay damage.

Rimu (*Dacrydium cupressinum lamb)*

Found in lowland to 600m above sea level. Some limited use in waka building. Not considered a carving timber but extensively used in the construction of both European and Māori structures. Heart timber moderately durable.

Kahikatea (*Podocarpus dacrydiodes*)

Part of the Podocarpus family of soft woods found all over New Zealand in lowland forests. Has little heartwood and suffers badly from insect and decay attack. Only used out of necessity in above-ground situations.

Pukatea (*Laurelia novae-zelandiae*)

Grows in swamps of lowland forests. Favoured for easy working when green. Noted use in the Wanganui district for making curved rafters, heke. The tree has a large flanged base which is good for cutting out these curved sections. Rated as non-durable.

Puriri (*Vitex lucens*)

Grows in the northern half of the North Island. Noted as being used for exterior tekoteko carvings because of its resistance to weathering, insect and decay damage.

Tukutuku wall panels

Classical panel construction consists of back vertical elements of toetoe kakaho stems, with horizontal slats of timber at the front. Panels were constructed on wooden stands to allow two weavers to work either side of the panel. There are a great variety of panel designs that have become universal in their use and adapted and modified to suit the style of the building. Materials traditionally used in their construction include:

Toetoe Kakaho (genus *Cortaderia*)

Kakaho is the name given to the flower stem of the New Zealand native toetoe. There are four species that all belong to the genus *Cortaderia* known as *C. toetoe, C. splendens, C. fulvida and C. richardii. Cortaderia* can be described as perennial tussocks. Stems are collected in late summer as the flower is beginning to dry but before mould and decay set in. The stems are trimmed and dried in the sun further so that an even yellow colouration develops. Later developments replaced toetoe kakaho with timber dowel, and eventually pegboard hardboard.

Pingao (*Desmoschoenus spiralis*)

Pingao is a sand-binding plant native to New Zealand. It grows mainly on the west coast beaches of the North Island. Pingao is harvested in the late summer after major growth has been completed, cut and dried to produce the golden yellow colouration. The fibres are hard and brittle and require care in preparation and weaving.

Kiekie (*Freycinetia banksii*)

The Kiekie plant grows in the bowls of large trees in the bush and along the forest floor. Leaves are picked and stripped to the required width before being dyed or boiled. Black colouration is traditionally produced by boiling the fibre in a tannate solution of either Hinau bark (*Elaeocarpus dentatus*) or Kanuka bark (*Leptospermum ericoides*). The treated fibre is then submerged into iron-rich mud called paru. The resulting reaction of tannic acid and iron produces a rich blue-black colouration on exposure to air. From the 1880s onwards a variety of organic commercial dyes were utilised. Paru dying is still practised in many areas. White kiekie was produced by boiling the fibre briefly in water and drying.

Harakeke flax (Phormium tenax)

Used commonly in earlier tukutuku panel work as a weaving fibre. Noted on Rongopai wharenui, 1888, and Rangiatea church 1841. Replaced by the stronger and more durable kiekie fibre in later years. Dyed in a similar manner to kiekie.

Laths timbers

Split totara is often used to produce the batten in earlier lath pieces. Machined half-round timber became common in the 1920s and later, in the 1970s, hardboard peg board was utilised, thus dispensing with the back vertical toetoe elements. Most laths were painted, earlier panels from the 1880s to 1910 often used white lead and red lead oil-based paints and later a range of paint types: oil-based until the 1940s then alkyd enamels.

Painted artwork

The application of paints to carvings and their decorative use in kowhaiwhai panels has been an important artform that has developed significantly since European paints were introduced. Painting replaced carved artforms in Ringatu wharenui during the 1880s and was utilised extensively to allow new expressions to be free of the constraints of ritualised carving traditions(Niech: 1993). The other function of paint coatings was to protect and extend the life of carvings on wharenui. Well maintained painted carvings have indefinite protection as long as the paint coating is retouched and renewed regularly to ensure the paint protects the timber surface from weathering. There has been a progression of paint materials used in wharenui including varnish-type coatings.

> Shark liver oil paint (Pre-European contact period)
>
> The traditional binding media of shark liver oil was heated and mixed with pigment to produce a drying oil paint. Major colours used were black, red ochre and white. It was replaced with introduced paints from around the 1830s onwards.
>
> Sizing (Contact phase)
>
> Generally organic binders, soluble in water, mixed with pigments and known as white washes and distempers.
>
> Drying oils (linseed and tung oil*)* Late Contact phase
>
> Came with the first European arrivals to New Zealand as a binder for paints and a component of varnishes. Probably applied to wharenui up until the 1930s, after which it was replaced by alkyd paint. Trade secrets of paint mixtures were kept by individual painters but usually consisted of linseed or tung oil in boiled or raw forms, with driers such as white lead and pigments.
>
> Alkyd resin paints (enamels) Modern phase
>
> These resins superseded drying oil paints around the 1930s because of their versatility in formulation and better film-forming properties. Paints were manufactured ready to use in a tin, ending the days of individual painters' recipes. As part of the development, primer and undercoat systems were developed.
>
> Emulsion paints (acrylic paints) Modern phase
>
> These paints came into use in the 1950s as an interior paint. They have since become accepted as an exterior paint and have been used widely. Earlier paints in this class were based on polyvinyl acetate resins. Now paints are based on acrylic resin.

Toetoe kakaho ceiling panels

Widely used up into the 1940s as a lining material for the roof spaces. The stems of the toetoe kakaho are collected, as for tukutuku preparation. Once dried, the stems are woven together to produce panels that fit behind the heke and batten framework. On older constructions, where heke and kaho provide the roof structure, this installation work was done before the roofing iron was laid. On more modern constructions the kakaho was installed on support timbers. Fluted timber match lining replaced toetoe in many buildings, but still retained the appearance of this finish.

Raupo (*Typha angustifolia*)

Raupo was extensively used as a wall cladding and internal insulation material in classical and Early) Contact phase wharenui. Raupo insulation is still present in early wharenui but is becoming rare as buildings are renovated and wall cladding and structures change over time. Raupo leaves were collected in the late summer after the growing period and dried ready for installation. Dried leaves were generally gathered into 120 mm – 200 mm diameter bundles and tied together to form cladding surfaces or insulation.

4. Statistics and fire safety education

4.1 Incidence of fires in traditional Māori buildings

The New Zealand Fire Service fire incident reporting system (FIRS) database (New Zealand Fire Service, 2002), recorded 81 structure fires at marae sites during the 15 years from 1986 to January 2002. Excluding the incomplete year 2002, during this time there was an average of five reported fires a year. These statistics are represented in Figure 4-1. Significantly, there were no fatalities as a result of fires at marae sites in the 15 years. In Figure 4-1 the proportion of the structure saved by Fire Service intervention is illustrated. The data presented here covers 19 structural fires on marae sites that the Fire Service attended over a four-year period from 1998 to 2001

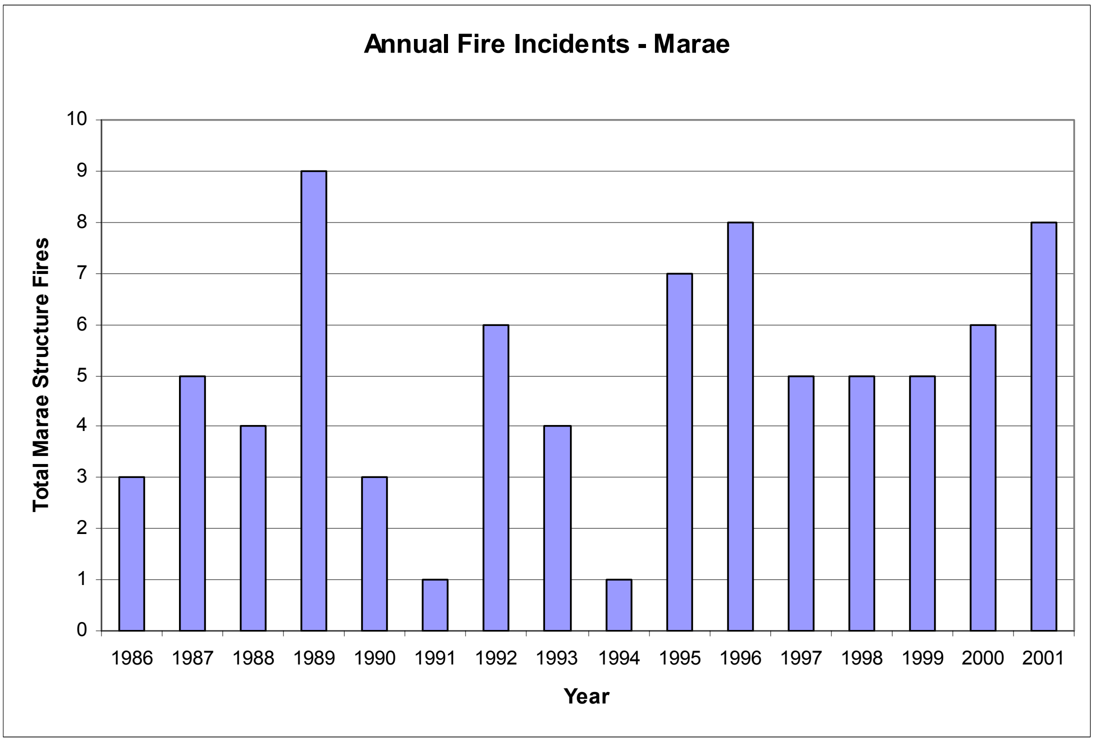

Figure 4-1: Annual marae fire incidents

(Source: NFIRS)

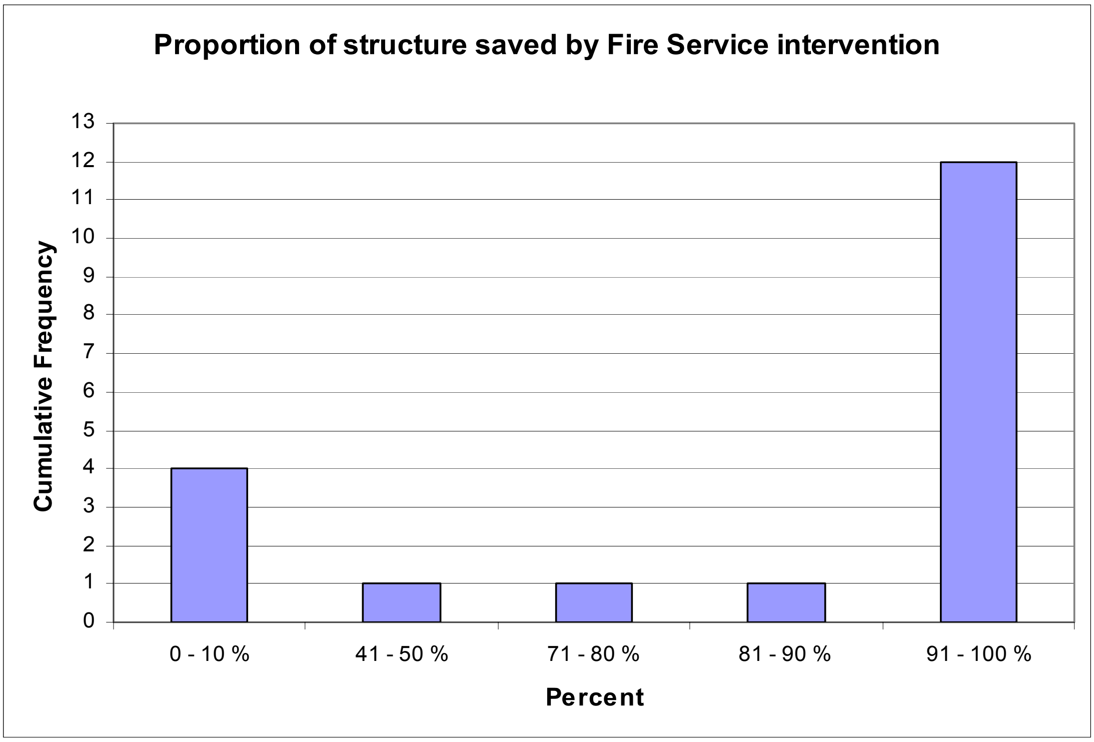

Figure 4-2: Proportion of structure saved by fire service intervention

(Source: NFIRS)

The statistics show that Fire Service intervention significantly increases the proportion of the structure saved from fire. This is highly dependent on the time taken to notify the Fire Service.

4.1.1 Limitations of the New Zealand statistics

The statistics reported are for fires on marae sites, including fires in buildings ancillary to the main wharenui. Fire Service statistics do not specifically distinguish which building on the sites were affected by fire. For example, fires at Te Kohanga Reo and 'recreational facilities' are included in the statistics. Further, due to the small numbers of incidents, the recorded incident rates may not be statistically significant.

4.2 Education findings

Thomas et al (2000), carried out research to determine effective fire safety strategies for Māori. The impetus for the research was the over-representation of Māori people in the fire death statistics. The research report, titled 'Determining Effective Fire Safety Strategies for Māori' surveyed the understanding of fire safety issues. These issues related to the home environment but general fire safety understanding is relevant to all applications in the building environment.

The report aimed to contribute to knowledge so that:

1. The Fire Service could gain a better understanding of how to promote and educate fire safety more effectively among those at risk.

2. Those at risk may increase their knowledge of fire safety.

An important finding from the research identifies Māori as particularly vulnerable to risk of death from fire in residential properties (Thomas et al, 2000):

- although ethnic origin of those deceased is not recorded in FIRS, it was possible to determine ethnic origin for the calendar years 1996 and 1997 by obtaining statements from investigating officers in each case. Māori, which makes up 15% of New Zealand's population, suffered 31% (1996) and 52% (1997) of deaths by fire in residential property.

With regard to the effectiveness of education information currently available to inform people about fire safety (Thomas et al, 2000):

- it highlighted the ineffectiveness of previous delivery methods of fire safety education to non-European ethnic groups and identified a need to develop new methods of delivery and new resource material aimed at specific at-risk ethnic groups.

Of importance in this study is the fact that 76% of those surveyed had attended a marae in the six months before being interviewed (Thomas et al, 2000). Of those surveyed, 83% thought the marae was the best place to speak to Māori about fire safety. This was significantly higher than any other response to this question and consistently high for both urban (83%) and rural (82%) participants. Many commented that the marae is the place where Māori meet to discuss important issues; further, Māori would be more comfortable in their 'own surroundings' and therefore more likely to listen and contribute to discussions. A very high (90%) proportion said they relied on word-of-mouth to be kept informed of what was happening in their area.

When considering the effectiveness of fire safety signs published in Māori, the survey participants were asked whether they could speak, read and comprehend the language.

Considering speaking Māori (refer Figure 4-3):

- 17% were unable to speak Te Reo at all
- 46% reported to be able to speak Te Reo a little
- 26% were able to speak enough Te Reo to get by
- 11% were able to speak Te Reo fluently.

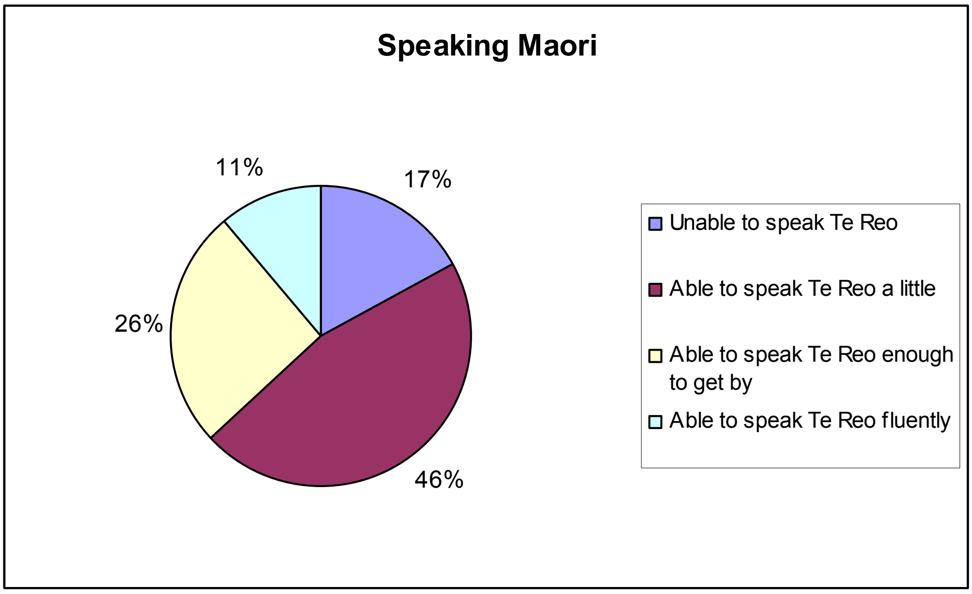

Figure 4-3: Ability to speak Māori
(Source: Thomas et al, 2000)

With regard to reading Māori (refer Figure 4-4):

- 16% reported no reading abilities in Te Reo
- 33% reported being able to read Te Reo a little
- 19% reported being able to read enough Te Reo to get by
- 28% were able to read Te Reo fluently.

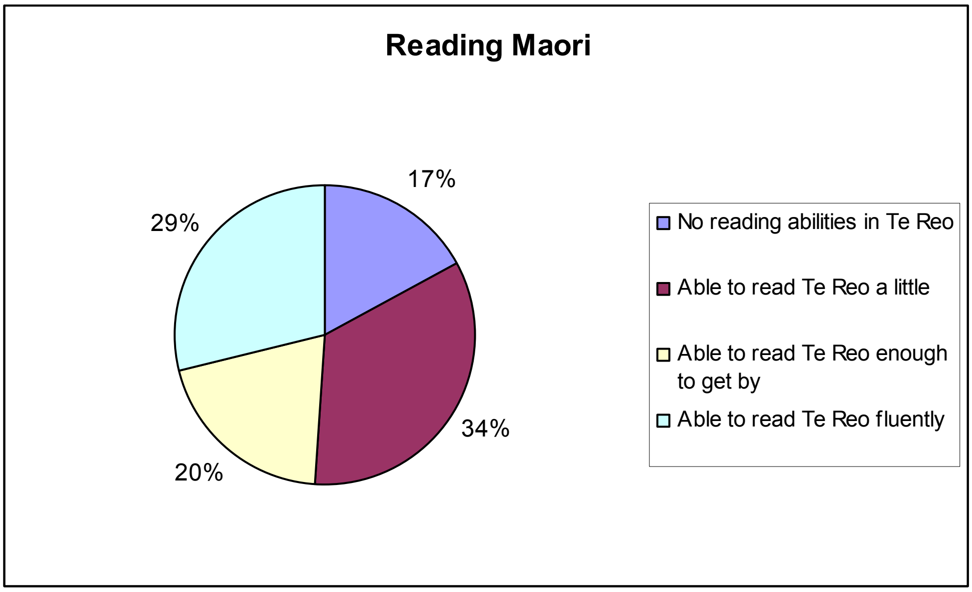

Figure 4-4: Ability to read Māori
(Source: Thomas et al, 2000)

Considering comprehension of the Māori language (refer Figure 4-5):

- 13% reported no understanding of Te Reo
- 38% were able to understand Te Reo a little
- 27% had enough understanding to get by
- 21% were able to understand Te Reo fluently

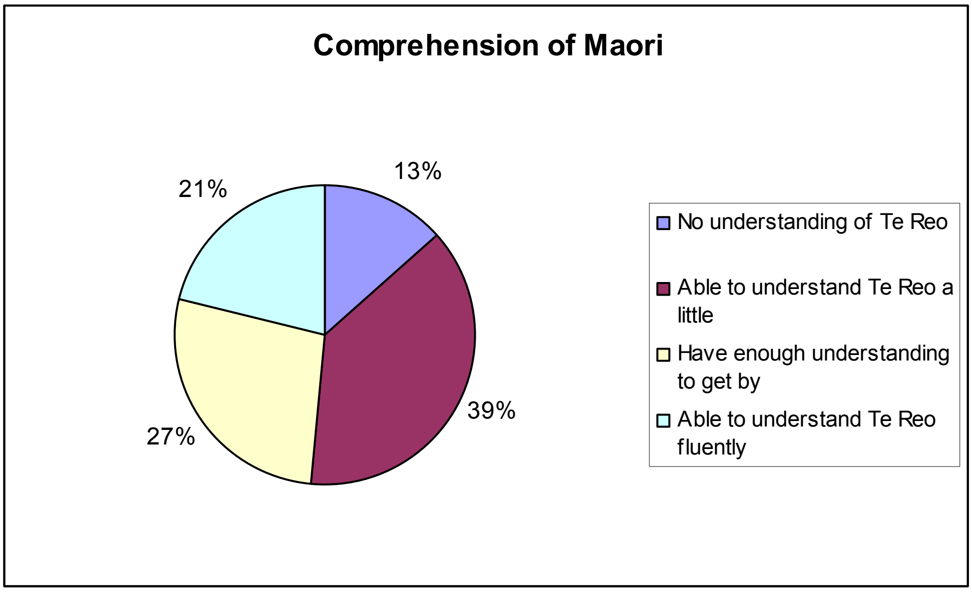

Figure 4-5: Ability to comprehend Māori
(Source: Thomas et al, 2000)

Reading, writing and comprehension of the Māori language influences the decision to introduce bilingual or Māori-language fire safety signs for the traditional building environment. With close to one-third of those surveyed being able to read and comprehend Māori language fluently, ranging to less than 20% having no understanding of the language, it is viable to introduce fire safety signs that display both English and Māori.

Guidance for the specification of these signs should be taken from the NZBC Acceptable Solutions F8/AS1 (Building Industry Authority, 2001).

4.2.1 Safety awareness

The understanding of 'fire safe' behaviour was also investigated by the fire safety strategy research (Thomas et al, 2000). The survey participants were asked to identify 'fire safe' and 'unsafe' behaviour from a series of photos showing everyday kitchen and bedroom scenes.

For the kitchen scene, participants distinguished the following as particularly unsafe behaviour: tea towels hanging on oven doors, lack of adult supervision, allowing children to cook and pot handles "sticking out" from stove. Twenty per cent of the participants reported that it was common for children to be cooking in the kitchen.

For the bedroom scene, participants identified the following as heightening the risk of fire: location of a burning candle and cigarette lighter being within reach of children. Forty-five per cent of participants said they identified with the scene and 24% stated that it was a normal situation for candles to be used in bedrooms. Very few survey participants did not use candles in the home. Half of those surveyed kept matches and lighters within reach of children.

In the survey, 43% of participants had a smoke alarm installed in their home with 13% believing a smoke alarm is unimportant. One-third of participants had an escape plan in case of a fire, which included making a quick exit and calling the Fire Service.

5. Marae fire safety: Fire Service intervention

There is a belief that if there is a fire anywhere in New Zealand the Fire Service will arrive and extinguish it and, in so doing, will be able to save both life and property. Although the Fire Service does intervene in urban situations regularly and save both lives and property, total reliance should not be placed on Fire Service intervention, particularly in remote rural locations.

Fire Service response to any incident relies on several factors, which can be divided into four categories:

- the time taken for the fire to be discovered
- the time taken for the Fire Service to be notified following discovery
- the time taken for the Fire Service to arrive at the scene of the fire
- the time for the fire fighters to set up and get water on the fire.

The first three influence the time taken for the brigade to arrive at the fire scene.

5.1.1 Discovery of the fire

This component of the notification process is the most variable time within the response scenario. The variability in this time is caused by the large difference between marae that have automatic detection systems installed that will detect a fire in the early stages and notify the appropriate person or authority, and those where discovery of the fire is reliant on someone actually seeing the fire. In some cases, where the marae is in a remote location without someone on site who could see the fire, the time taken to discover the fire could be far in excess of the time taken for the fire to destroy the building. This is highlighted by the fact that in some rural fires the first indication of a fire is that the destroyed building is discovered. In the case of a marae it would be expected that a fire would be discovered while it is still burning. However, the damage to the building at the time of discovery may still be too extensive to save it, even if the fire is extinguished.

5.1.2 The time taken for the Fire Service to be notified

The time taken for the nearest Fire Service brigade to be notified is reliant on the person (or system) that discovers the fire and their proximity to communications equipment (either through telephone or direct connection to the Fire Service monitoring system). The delay is based on the time taken from the moment the fire is discovered (either by a person or an automatic system) until the correct person is notified. This time can range from zero (there is an automatic system installed in the marae and the notification process involves a direct connection to the Fire Service monitoring system) to hours (the marae is remote from a telephone and to make the 111 call the person who discovers the fire has to travel to a telephone).

It is important to note that this ‘alert’ time is completely separate from actions taken by the Fire Service. These times highlight that it is possible that conditions within the structure would be untenable and that the structure would be badly damaged before the Fire Service is notified of the fire.

5.1.3 Fire Service response time

The Fire Service response time is the time from notification of a fire to when the first appliance arrives at the building. This response time is dependent on whether the ,marae site is within an urban fire district or not. If the marae site is within an urban district then there is a reasonable probability that the Fire Service will be able to intervene to protect exposure and prevent the fire from spreading to additional structures. However, the ability to save the building is questionable unless there is passive fire resistance built into the structure or if active fire protection systems are installed.

The problem of response can be highlighted by the following examples of marae sites around Lake Rotorua:

- **Lake Rotorua Marae**

Around Lake Rotorua marae are located along the lake shore. For several of these marae (Pikiao and Mataikotere maraes) there is a significant distance between the marae and the nearest brigade (more than 30 km in the case of Pikiao) and because of this, there would be a long response time for the first responding fire appliance and even longer for any appliances following from further away.

The location of the Awahou Marae presents a different problem in that the road access is difficult for vehicles (especially fire appliances). So in this case, even though the travel distance from the nearest brigade (Ngongotaha Volunteer Brigade) is not great, there would be an extended setting up time before fire fighting operations could commence. This setting up procedure would involve getting the hose from the appliance to the marae site.

- **Waihaha Marae**

The problems in getting a fire appliance to this marae are considerable: there is no road access (access is generally made by either foot track or boat). Therefore there is nothing that the Fire Service could do to intervene in the event of a fire. The nearest responding brigade would be the Turangi Volunteer Brigade, more than 40km away, so even if there was good road access to the site, a fire would have had a significant time (expected to be half an hour) to grow and damage the building.

- **Maungapohatu Marae**

Access is the major problem with any attempt at fire fighting on this marae. The nearest brigade is based at Murupara which is more than 40km from the base of the access to the marae. The roads between the brigade and that point are unsealed and slow road speeds are necessary for safety. Therefore an extended response time is expected. Additionally, the marae is not accessible by road and is too far away from a point where an appliance could access the hose to be run from it.. Therefore, if a fire does develop at the marae, a total loss is expected unless it can be extinguished in its early stages.

- **Opureora and Rangiwaea marae**

These marae are on islands off Tauranga (on Matakana Island and Rangiwaea Islands respectively). There is no road access from the mainland to the islands so any Fire Service response would initially be by boat to the island (the barge that will take the appliance across takes approximately 18 minutes to make a one-way trip) and so the travel time is expected to be extended. There is a rural fire party on Matakana Island and this would be the first responding unit to a fire at Opureora Marae. However, this party is equipped with two small appliances and no structural fire-fighting equipment (breathing apparatus etc) and so would only be able to mount a limited external attack on any fire. Again the time from notification to the arrival of the first appliance from the mainland would be about half an hour, during which time a fire is likely to have caused significant damage to the building. Rangiwaea Marae faces more difficulties than Opureora because there is no fire party present that could at least mount a limited attack from outside the building.

- **Te Ohaaki Marae**

This marae is on the back road between Taupo and Rotorua. Road access is good as are the road conditions leading to the marae. However, the problem is that the nearest responding brigade (Taupo) is 35km away. This leaves a long travel time for the brigade and, as such, extensive damage may occur to the structure during this time.

5.1.4 Comparison of Fire Service response against fire spread and development

The majority of marae do not have active fire protection systems or detection systems installed. Therefore there is no reliable way to predict when the fire would be discovered and, correspondingly, there is no way of determining the size or severity of the fire once discovered.

5.1.5 Water supplies

Most marae are outside reticulated areas where there is effectively an unlimited water supply for fire fighting. On-site water storage and water sources must be relied on for the fire fighting water supply. In many cases these on-site supplies are primarily for drinking and do not contain sufficient capacity for an extended fire-fighting operation, nor is there ready access to those supplies as no brigade inlets are attached to the tanks.

5.1.6 Fire Service recommendations

The only reliable conclusions that can be drawn from Fire Service response to marae sites is that the lack of detection and warning systems, coupled with the remoteness from the local brigade, means that the Fire Service cannot be relied on to prevent loss of life and extensive structural damage in the event of a fire.

In summary, it is the Fire Service's view that if lives are to be saved and the building is to be preserved in the event of a fire it is up to the building owners to ensure the building is protected. This would mean early warning systems installed to protect life (especially when there are sleeping occupants within the building) and active fire containment/suppression systems to protect the building.

6. Fire safety of buildings legislation

There are two main pieces of legislation that deal with the fire safety of buildings: the Building Act 1991 (New Zealand Government, 1991 No. 150) and the Fire Service Act 1975 (New Zealand Government, 1975 No. 42).

The Building Act 1991 has two requirements for fire safety (Caldwell, C. & MacLennan, H., 2000):

1. If a building is being altered, but the use is not being changed, the territorial authority (that is, the city or district council) must be satisfied on reasonable grounds that after alteration the building will comply with the provisions of section 38 of the New Zealand Building Act 1991 for means of escape from fire 'as nearly as is reasonably practicable, to the same extent as if it were a new building';

2. If the use of the building is being changed, the building must comply with the provisions section 46 of the Building Act 1991 for means of escape from fire, protection of other property, and structural and fire rating behaviour 'as nearly as is reasonably

practicable, to the same extent as if it were a new building'. This means that in addition to the means of escape, the spread of fire must be addressed.

The Fire Service Act 1975 requires specified buildings to have an evacuation scheme. The Act specifies which types of buildings are required to have evacuation schemes. The Regulations are applicable to most buildings, including heritage buildings, used by the public. Any building where more than 10 people are employed, where more than 100 people assemble, or where accommodation for more than five people is provided, requires an evacuation scheme. These categories cover the use of traditional Māori buildings. If the building does not have an approved fire sprinkler system, then the evacuation scheme must be approved by the Fire Service.

7. Protection and preservation of historic buildings

7.1 New Zealand ICOMOS Charter for the Conservation of Places of Cultural Heritage Value

The International Council on Monuments and Sites (ICOMOS) New Zealand charter for the conservation of places of cultural heritage value (ICOMOS, 1993) defines that the purpose of conservation is to care for the places of cultural heritage value, their structures, materials and cultural meaning.

The charter requires an understanding of indigenous cultural heritage defining family, hapu and tribal groups and associations as inseparable from identity and well-being, thus having particular cultural meanings. With respect to the conservation of traditional Māori buildings, the ICOMOS (1993) charter states the following:

> *The Treaty of Waitangi is the founding document of our nation and is the basis for indigenous guardianship. It recognises the indigenous people as exercising responsibility for their treasures, monuments and sacred places. This interest extends beyond current legal ownership wherever such heritage exists. Particular knowledge of heritage values is entrusted to chosen guardians. The conservation of places of indigenous cultural heritage value therefore is conditional on decisions made in the indigenous community, and should proceed only in this context. Indigenous conservation precepts are fluid and take account of the continuity of life and the needs of the present as well as the responsibilities of guardianship and association with those who have gone before. In particular, protocols of access, authority and ritual are handled at a local level. General principles of ethics and social respect affirm that such protocols should be observed.*

The charter (ICOMOS, 1993) states that appropriate conservation professionals should be involved in all aspects of conservation work. Indigenous methodologies should be applied as appropriate and may vary from place to place. Conservation results should be in keeping with their cultural content. All necessary consents and permits should be obtained.

Conservation projects should include the following (ICOMOS, 1993):

1. Definition of the cultural heritage value of the place, which requires prior researching of any documentary and oral history, a detailed examination of the place, and the recording of its physical condition.

2. Community consultation, continuing throughout a project as appropriate..

3. Preparation of a plan that meets the conservation principles of this charter..

4. The implementation of any planned work. .

5. The documentation of any research, recording and conservation work, as it proceeds.

The conservation method, as defined by the ICOMOS charter (1993) and followed by the Historic Places Heritage Guidelines, states that conservation should:

1. Make use of all relevant conservation values, knowledge, disciplines, arts and crafts..

2. Show the greatest respect for, and involve the least possible loss of, material of cultural heritage value.

3. Involve the least degree of intervention consistent with long-term care and the principles of this charter..

4. Take into account the needs, abilities and resources of the particular communities. .

5. Be fully documented and recorded.

All places of cultural heritage value should be assessed as to their potential risk from any natural process or event and appropriate action taken to minimise the risk, including a risk mitigation plan.

The charter (ICOMOS, 1993) also has requirements to ensure:

- invasive investigation is minimised and sympathetic to the environment

- where contents of a place contribute to its cultural heritage value they should be regarded as an integral part of the place. This includes carving, painting, weaving, stained glass and other arts.

- records of the research and conservation of places of cultural heritage value should be placed in an appropriate archive and made available to all affected people.

Conservation may involve an increasing extent of intervention, non-intervention, maintenance, stabilisation, repair, restoration, reconstruction or adaptation. Where appropriate, conservation processes may be applied to parts or components of a structure or site (ICOMOS, 1993).

Recreation, meaning the conjectural reconstruction of a place, and replication, meaning to make a copy of an existing place, are outside the scope of the ICOMOS (1993) charter.

7.2 Conservation plans

A conservation plan is '*a way of working out what is important about an historic place, and a means to help you decide on the best way of using and of caring for the place – essentially, how to conserve it*' (Bowron, G. & Harris, J. 2000).

There are a variety of levels of detail which can be provided in a conservation document and form the basis for developing a fire safety system which is sensitive to the use and structure of the building. A conservation plan is the most extensive and complete document required to guide the future use and conservation of an historic place (Bowron, G. & Harris, J. 2000). Other types of conservation document include:

- **a cultural heritage assessment** – identifies the existing fabric of the place and its origin

- **a conservation or structural report** – assesses the current condition of the place

- **a cyclical maintenance plan** – concentrates on how to maintain a place in its existing state

Four steps are identified as the sequence of events for creating a conservation plan for a heritage building: *investigation; assessment; policy; action*.

Investigation

Investigation involves researching the history, construction and setting of the place. It looks at issues such as previous uses, and considers wider issues such as the social, economic, political and spiritual factors shaping the use of the place. Consideration of the intangible values, such as spiritual factors, is of particular relevance to traditional Māori buildings. Investigation can also involve researching the individuals, families, iwi, hapu, institutions carvers, weavers, painters, religious associations, architects, engineers, and builders and whaihanga connected with the place.

The guidelines outline a methodology for undertaking research for the heritage building investigation. The methodology is outlined as follows (Bowron, G. & Harris, J. 2000):

- the history of the construction of the place
- the construction technology and materials
- cultural/architectural influences that have affected the form, floor plan, fabric and detailing of the place
- a list of modifications, including dates
- functions of the place and its parts
- the existence and type of lost fabric
- comparisons between documented and surviving fabric
- comparisons with similar places
- documentation of wallpaper and other wall treatments and interior features and fittings
- paint analysis, interior and exterior
- collections of furnishings, tools, machinery or any other artefacts original to the structure should be documented and photographed in situ
- any other factor helpful in the understanding of the place.

Heritage assessment

For general heritage buildings it is important to develop a system of determining the heritage value of a structure. Four general criteria are considered when undertaking a heritage assessment: aesthetic, scientific, social and historic (Bowron, G. & Harris, J. 2000).

‘Aesthetic’ considers the formal qualities of the fabric and setting. It addresses the design and architectural aspects of the place. ‘Scientific’ is concerned with the importance of past human activity in the place and with the survival of that evidence in the original fabric. ‘Social’ involves the notion of a spiritual, traditional, political, national or any other cultural sentiment expressed by a group. ‘Historic’ is the ability to demonstrate an association with persons, ideas or events. It must include an analysis of the intangible aspects of the place’s past (Bowron et al 2000).

The significance of parts of the place is then rated according to a three-level scale:

(A) Exceptional significance

(B) Considerable significance

(C) Some significance.

The category ‘negative’ is also added to be assigned to elements which detract from the historic significance of the place (Bowron, G. & Harris, J. 2000).

Although this type methodology is applicable to assessing the relative significance of the physical fabric of traditional Māori buildings, overall significance is difficult to determine from a Māori perspective. The intangible values can only be determined through a Māori framework of thinking and approach. Concepts such as wairua, mauri, mana and whakapapa are not measurable through a system of ranking and comparison. Often a state of tapu is applied to a whole structure and cannot be distinguished for individual parts of the building. Also, the nature of these structures is that they are single-room structures, not complicated by multiple rooms and levels; therefore a whole statement on significance can be applied. A clear statement of relationship between the cultural heritage building and the associated Māori community is the most important value to convey within a conservation heritage assessment of the wharenui.

Conservation policy

Of particular importance to traditional Māori buildings is the inclusion in the conservation policy of a statement outlining the cultural heritage significance of the place. The conservation plan guidelines recognise the following factors to consider when developing a conservation policy (Bowron, G. & Harris, J. 2000):

1. **Requirements of the owner and occupier** – the existing and anticipated uses of the place may be considered, together with possible community needs where appropriate, and the availability of resources.

2. **Existing condition of the place** – a general assessment of the physical condition of the elements of the place.

3. **Requirements of the tangata whenua** – state the actions necessary to ensure compliance with any requirements of the tangata whenua.

4. **Historic Places Act 1993** – state the implication of registration, covenants, heritage orders and any other effect the Historic Places Act (New Zealand Government, 1993 No. 38) may have on the fabric and setting of the place.

5. **Local authority plan provisions** – implications that local authority plans may have for the fabric and setting of the place.

6. **Compliance with statutory codes** – such as requirements to comply with the provisions of the New Zealand Building Code (BIA, 2001).

7. **Threats** – these may include natural threats, such as vegetation and erosions, and threats arising from visitors or use.

After investigation, assessment and understanding, recommendations for conservation can be made.

7.3 New Zealand Historic Places Trust guidelines for fire safety

A set of Heritage guidelines are published by the New Zealand Historic Places Trust which outline the conservation requirements to be considered when preserving an historic building. The Heritage guidelines comprise 10 volumes covering the following topics:

1. Historic timber structures.
2. Historic brick structures.
3. Historic stone structures.
4. Preparing conservation plans.
5. Altering heritage buildings.
6. Earthquake strengthening.
7. Fire safety.
8. Making historic buildings accessible.
9. Altering historic churches.
10. Developing heritage buildings.

The following section details Volume 7, Guidelines for Fire Safety (Caldwell, C. & MacLennan, H., 2000) and the significant parts of other guidelines which relate to the fire protection of traditional Māori buildings.

The aim of the Guidelines for Fire Safety document is to identify broad areas of concern and offer suggestions to help increase the fire safety of heritage buildings without compromising their heritage character and value. Two particular problems in terms of fire safety for heritage buildings are identified (Caldwell, C. & MacLennan, H., 2000):

1. They often incorporate construction features that are a risk, such as exposed timber floors, walls lined internally with combustible materials, and wooden mouldings.
2. There is a potential for conflict between the measures that are needed to protect a heritage building from fire and the retention of its heritage character and value.

The Guidelines for Fire Safety (Caldwell, C. & MacLennan, H., 2000) outline eight steps to ensure that an optimum fire safety solution is designed for the heritage building:

1. **Assess heritage significance** – it may be necessary to develop a cultural heritage assessment for the building. The assessment should '*identify the spaces and elements that make a particularly important contribution to the overall significance of the place*'. It is stated that sometimes a full scale conservation plan is necessary, particularly if '*the provision of a fire safety system is part of a larger project, or the building is one of outstanding heritage value*', or simply statements of the whole building and place, as is the case with conservation reports and cyclic maintenance plans.

2. **Develop fire safety objectives** – identification of the acceptable level of fire loss is the first step in the fire design. The levels of fire loss in order of increasing fire safety as described in the guidelines are:
   a) meet the minimum fire requirements of the NZBC, providing minimum statutory life safety and protection of adjacent property
   b) limit damage to the firecell of origin
   c) limit fire damage to the room of origin
   d) limit fire damage to the minimum possible.

3. **Conduct risk assessment and develop fire safety strategy** – the level of fire risk is described as the result of a complex interaction between a variety of factors including the start of the fire, the growth and spread of the fire, the response of the building components to the fire, the response of the occupants in the presence of fire, and the response of the firefighters.

4. **Document fire safety system design which meets objectives and statutory requirements** – the three main objectives with regard to fire safety from the NZBC are:

   a) ensure that the occupants of the building are able to escape in the event of fire
   b) to make allowance for firefighters to enter the building to undertake search and rescue operations
   c) to limit the spread of fire from the burning building to neighbouring properties.

   The two methods of achieving compliance with the fire requirements of the NZBC are:

   (1) fire design to meet Building Industry Authority (BIA) acceptable solutions
   (2) fire design as an alternative solution.

5. **Identify and evaluate fire safety options within a conservation context** – the aim is to provide the greatest level of fire safety without compromising the heritage significance of the place. The guidelines recommend the following conservation standards: minimal change, sensitive change, distinguishing new from old, reversible work, documenting changes and advice from heritage professionals.

6. **Obtain building and resource consents.**

7. **Implement works.**

8. **Maintain components of the fire safety system.**

7.3.1 Fire design concepts

The guidelines identify nine fire design concepts applicable to the fire safety system for heritage buildings. These concepts consider: escape routes, fire and smoke separations, choosing materials to restrict the growth of fire, smoke control, fire detection, fire suppression systems, manual call points, fire alarms, exit signs and emergency lighting, firefighting equipment, fire safety management.

The Fire Safety Acceptable Solutions (Building Industry Authority (BIA), 2001) require a minimum number of emergency exits and they specify maximum travel distances between any one part of the building and the nearest exit. Heritage buildings are required to meet these specifications. The Acceptable Solutions (BIA, 2001) also have requirements, such as minimum widths for staircases, ramps, passageways and doors. The upgrade to meet the requirements for means of escape must not have a negative impact on the heritage building, compromising its appearance and reducing its heritage value and significance. The guidelines state that it might be preferable to design an Alternative Solution, allowing non-prescriptive options to be incorporated in the design.

Fire and smoke separation is achieved by dividing the building into firecells. The partitioning into firecells is required to be non-intrusive and sensitive to the building structure.

A building's design, construction and materials can be used to minimise the spread of fire, smoke and toxic gases within the building (Caldwell, C. & MacLennan, H., 2000). Of particular relevance to traditional Māori buildings is the possibility of treating existing combustible materials with a fire-retarding agent that will provide resistance to the spread of flames, or hard surfaces that can be protected by the use of intumescent coatings.

Smoke control can be achieved by combinations of passive separations, extract systems (natural or mechanical) and pressurisation systems.

The most common fire-detection systems are smoke detectors and thermal/heat detectors. Smoke detectors provide the earliest warning of a fire. Detectors can be placed unobtrusively in the building fabric and can sometimes be camouflaged within wall elements or ceiling patterns. Their colours can be specified to match the walls or ceiling. If electric cabling is required it should be concealed wherever possible and should be laid out to ensure minimum intervention with the building fabric (Caldwell, C. & MacLennan, H., 2000).

Fire suppression systems provide the most protection to property. The most common are sprinkler systems such as: wet systems, dry systems, pre-action, water misting and external drenchers. In the case of heritage buildings, the layout and position of the system requires careful consideration to ensure it is as unobtrusive as possible.

Manual call points, fire alarms, exit signs and emergency lighting are required to aid in the evacuation of the building. They must be highly visible but can be installed to have the least impact on the building structure.

Firefighting equipment includes hand-held fire extinguishers, hydrants and fire hose reels. These are required to be sensitively located but able to be found easily in an emergency.

Once a fire safety system is installed in a building it is important to ensure the system is managed correctly and effectively. Particular to heritage buildings is a requirement for a fire safety manual. The manual should highlight the actions necessary to prevent a fire as well as the maintenance needs of, and procedures for, all the fire safety features (Caldwell, C. & MacLennan, H., 2000).

In cases where an acceptable level of fire safety cannot be achieved without destroying much of the heritage building fabric, it may be feasible to instead restrict the number of people who can occupy the building at any one time, or to limit the types of use of the building (Caldwell, C. & MacLennan, H., 2000).

7.4 Evaluation and application of fire safety systems within a conservation context

The guidelines emphasise the importance of conservation processes that are sensitive to the physical structure and the cultural and spiritual significance of the building. They look at preservation, not just the building fabric but also of the context and surroundings of the building.

This philosophy is to be taken into context when considering the fire protection of traditional Māori buildings. Its application should take a holistic approach, with the aim of any installation being non-intrusive and sensitive, and to incorporate liaison with interest groups.

The methodology is the same for new structures. Although it may be less intrusive to have sprinklers installed in a new structure, it remains important to assess the significance of the place and its surroundings, and to put a 'value' on its preservation.

Documentation should be maintained throughout the process. For safe keeping, it is suggested that it be located at a remote site in case of fire: for example , at the local fire station, library or archives.

When devising a fire safety system for a traditional Māori building there is a finite number of possibilities under the categories of active and passive fire protection systems. The importance of the fire safety system for traditional Māori buildings is that it has to work within the building's constraints:

1. The system is, in general, required to be retro-fit.
2. The system is required to be sensitive to the cultural significance of the building.
3. The system is fundamentally for life safety but needs to consider property protection due to the building's cultural significance.
4. The system may be constrained by issues such as remote rural location, water supplies and availability of electricity.

Further considerations are purchase cost, ease of installation, and the level and ongoing expenses of systems maintenance.

8. Case studies

This section looks at a sample of the types of wharenui construction. Particular emphasis is given to the traditional construction techniques, types of construction materials, internal surface finishes and the way the use of the building and cultural aspects influence the construction and layout.

8.1 Raukawa Marae

The following is a case study of Raukawa Marae, Ōtaki.

8.1.1 History of Raukawa Marae

(*Historic Places trust – description of Raukawa Marae*)

In 1853 the original Raukawa Wharenui was opened on the same site as the present building. The building was constructed of pitsawn timber, uncarved but with painted patterns, it lasted (with renovations in 1885-86) until about 1930.

Construction of the present Raukawa Wharenui began in 1930, with the fully decorated building officially opened on 14 March 1936. The walls and foundations are of concrete and a concrete pillar, supporting the ridgepole, stands in the centre of the porch. Atop the concrete pillar, where one would normally find a koru-carving, there is a full-length figure carved in the round, and above this, crowning the apex of the roof is the tekoteko Motai, an ancestor of Raukawa (refer Figure 8-2).

Other ancestors are depicted on the poupou (carved slabs) around the walls. Separating these carvings are tukutuku panels, each pattern being the same as the one facing it on the opposite wall. The rafters, heke, edging boards heke tipi, and the underside of the ridge pole tahuhu are decorated with painted kowhaiwhai designs of perfect symmetry and variety. For the lining of the inner walls and roof, the yellow stems of the toetoe kakaho (genus *Cortedaria*) were used in great quantity – 125,000 were required – and the use of this traditional material rather than one of the modern substitutes commonly seen in present day wharenui, adds greatly to the finish and distinction of Raukawa and enhances the beauty of its artwork.

The decorative style of Raukawa, and especially that of the carvings, has been described as 'universal'. Ngati Raukawa claim to be connected, by ancestry or marriage, with all the North Island tribes and in recognition of this fact their wharenui was adorned in styles representative of them all.

8.1.2 Raukawa Marae site visit

Raukawa Marae is in Ōtaki township, on the Kãpiti Coast, on the west coast of the North Island (refer Figure 8-1).

Figure 8-1: Raukawa Marae – Ōtaki

Construction of the marae began in 1930 with the fully decorated marae completed in 1936 (refer Figure 8-2). More recently a store room and ablutions block have been linked into the side of the marae (just visible on the left of Figure 8-3).

Figure 8-2: Raukawa Marae – decoration of marae completed in 1936

A particular construction feature of this wharenui is the concrete shell which encases the more traditional construction (refer Figure 8-3).

Ablutions and store attached

Figure 8-3: Concrete shell encases traditional construction

A cross-section of the meeting house wall would reveal a concrete outer shell covering vertically aligned and laced together panels of toetoe, with the interior lined with tukutuku panels of horizontally placed strips of tōtara (timber) woven together.

Figure 8-4: Raukawa Marae – internal surface finishes

The internal linings of the wharenui are made from natural materials. The walls have three significant components:

1. Tukutuku panels – these are panels comprising horizontal slats of timber woven together with kiekie and pingao. Toetoe kakaho used for the vertical elements supporting the back of the panels.
2. Carvings – the carvings are totara and are treated with linseed oil.
3. Panels – the lower part of the wall is timber.

The ceiling is panels of toetoe kakaho stitched together. The toetoe is untreated and Figure 8-5 and Figure 8-6 show the variations in external and internal weathering.

Figure 8-5: Ceiling lining of porch – toetoe thatched together

Figure 8-6: Internal ceiling linings

The totara rafters and purlins have painted kowhaiwhai decorations.

The timber floor of the wharenui is covered with carpet. When used for sleeping, often woven flax mats are placed on the floor. The main exit has been supplemented with 'push-out' windows at the rear, hinged to act as an alternative means of escape, and a door has been added linking the adjoining buildings. This door has been camouflaged so as not to impact on the aesthetics of the building. Exit signs do not label the door. The camouflaged door is not fire rated. The marae use influences the types of fire safety systems which would be appropriate.

Figure 8-7: Additional exit sympathetic to internal surface finishes

Figure 8-8: Door lined with tukutuku panelling for camouflage

Stand alone point-style smoke alarms have been installed in the wharenui and adjoining storage area (refer Figure 8-6). The dining room, kitchen and corridor between them and the wharenui do not have smoke alarms.

The wharenui is directly connected to the ablution block which joins to the dining room and kitchen area (refer Figure 8-3). There is no fire separation, either provided by a fire-resistant wall and door or compartmentation in the roof cavity, between the wharenui and the adjoining buildings. The roof of the wharenui is constructed in corrugated steel with timber rafters covering the traditional roof and ceiling construction described previously (refer Figure 8-3).

Storage of foam mattresses and linen pose a concern for this marae. Smoke alarms in this area provide early warning in the event of a fire. The kitchen and dining areas are directly connected to the wharenui. Fire separation would prevent the spread of fire and smoke from this potential source to the sleeping area in the wharenui. The dining/kitchen are of contemporary construction with it being less intrusive to add signage and fire-resistant construction.

In the wharenui, a more subtle fire safety approach is required. Potentially, floor lighting to illuminate exits in the event of fire. Also fire separation construction would prevent fire spreading. Risk analysis would show the most likely source of fire to be from the kitchen/dining area and it is important to fire-separate this area from the wharenui.

8.1.3 Raukawa Wharenui construction

The foundations of the wharenui are continuous cast concrete walls approximately 270 mm thick. They support cast concrete walls 120 mm thick. The timber floor of the house sits within the concrete walls. There are six 100 mm x 75 mm bearers that run the full length of the house; these are supported on concrete foundation blocks made by filling four gallon kerosene tins with concrete. Resting on the bearers and running across the house are 100 mm x 50 mm floor joists at 520 mm centres approximately. At the outside edge these joists rest on a lip in the concrete foundation wall.

8.2 Tapu Te Ranga

Tapu Te Ranga incorporates a more contemporary design of marae (refer Figure 8-9). The marae buildings at Tapu Te Ranga aim to enforce the idea of sustainable living by using recycled material. The pitched roof and construction style is the same as that of more traditional style marae.

Figure 8-9: Contemporary style of marae building

Note the elaborate decorations constructed of flammable material and only one entrance and exit to some of the rooms (refer Figure 8-10).

Figure 8-10: Artwork and decorations

Traditional Māori style construction has been integrated with more contemporary building construction

8.3 Hinerupe

8.3.1 Background

On 13 April 1996 a fire completely destroyed Rongomaihuatahi Wharekai and severely damaged Hinerupe Wharenui (built c.1938) at Te Araroa in the North Island. The fire originated in the wharekai (kitchen/dining building) and spread to the wharenui via a recently constructed ablution block linking the two buildings. Fire burnt through the roof cavity of the wharenui into the interior, significantly damaging tukutuku, kowhaiwhai and carvings, some of which dated back to 1880.

The fire completely destroyed the wharekai and Hinerupe was demolished down to the foundations and floor, these being the only two structural areas that survived intact. A total of 110 carvings and three heke were recovered; tukutuku and kowhaiwhai work on the interior were lost. The building did not have a fire safety system installed.

8.3.2 Conservation assessment

A conservation assessment was undertaken to assess what was salvageable from Hinerupe and to determine restoration methods (Tupara, 1996).

8.3.3 Damage

The following outlines the damage and cultural loss due to the fire (Tupara, 1996):

- tukutuku – little of the tukutuku was saved as many of the panels were damaged beyond retrieval, some panels having only fragments remaining

- kowhaiwhai – the kowhaiwhai work was almost completely lost. The heat in the ceiling caused the loss of all the heke and much of the tahu. The whole ceiling area was assessed as non-retrievable.

- whakairo – most of the carvings were retrievable. On the interior of the building all the carvings were damaged by the fire with the degree of damage varying. The lower parts of the panels had only the varnish burnt with the timber beneath still solid. The burnt varnish was able to be removed. In the centre of the panels, the timber, scorched 4 mm-5 mm deep, was able to be consolidated back to the solid timber behind. The top of the carvings experienced the worst charring but in most cases these areas were also able to be consolidated. Many of the carvings were structural to the building. Even after treatment the strength of the carvings, as a structural element, could not be guaranteed. Alternative structural considerations were required for the design of the new building.

8.4 St Mary's Church

8.4.1 Description

St Mary's Church, Tikitiki, Te Arawa, is an example of where a fire safety solution has been an integral part of the conservation plan for a building with cultural significance (Cochran et al, 1999).

St Mary's is an Anglican church which was built as a memorial to Ngati Porou servicemen who lost their lives in World War I. Construction of St Mary's began in 1924, and was completed in February 1926. The exterior of the timber-framed 170 m^2 church is clad with timber weatherboards and corrugated galvanised steel. Along with conventional stained-glass windows, the interior is decorated with tukutuku weaving, painted kowhaiwhai and traditional carvings, some of which were produced by local carvers and gifted to the church.

8.4.2 Conservation plan

In 1999, relevant interest groups were consulted to determine the conservation approach for the building. It was agreed that the church should be repaired and conserved to the highest standards with no alteration to the conception and design of the original work of 1924 (Cochran et al, 1999).

The conservation work was required to meet the standards of the New Zealand Lottery Grants Boards', Environment and Heritage, and follow the conservation principles set out in the ICOMOS Charter for the Conservation of Places of Cultural Heritage (refer Section 1.1). The requirements include (Cochran et al, 1999):

- repairing the building, associated artworks and stained glass with original or matching materials, retaining as much as possible of the original fabric. (Repairs to a technically higher standard than the original are allowed where the life expectancy of the element is enhanced.)

- restoring lost features only where there is clear evidence of the original form and detail

- maintaining the building to a high standard so that it is always weatherproof, tidy and functional. Maintenance should be carried out regularly and according to a plan.

- identifying new materials used in maintenance and repair to distinguish them from the old

- keeping records of maintenance and repair work.

The conservation plan for the building considered not only the fire safety issues but the upgrade of the entire structure. The following is a summary of the required repair work (Cochran et al, 1999):

- timber cladding – repairs were needed to eaves, rafter ends and barge boards in five or six places

- stormwater disposal – some downpipes discharge on to the ground. They should be connected to a new stormwater disposal system.

- electrical – the electrical wiring needed checking by a registered electrician to ensure it was safe. The fluorescent tube lighting of the naive detracts from the beauty of the space and it was recommended that the lighting be completely revised.

- painting – although exterior paintwork was in reasonable condition it was recommended that the building be repainted as part of the conservation programme

- fire protection – the church had several fire extinguishers that required recharging but was otherwise unprotected from damage by fire. It was recommended that an automatic fire sprinkler system be installed.

- gateway – repairs were required to the concrete arch over the gateway, and to the gates themselves.

The structural work was estimated to cost $82,500 excluding GST, of which approximately half was for the design and installation of the automatic fire sprinkler system.

8.4.3 Fire protection

St Mary's Church is considered to be of great cultural value and irreplaceable. The conservation plan proposed to install a fully automatic fire sprinkler system to protect those using the building and to prevent its loss or damage by fire. The sprinkler system was required to meet the requirements of NZS 4541:1996 Automatic Fire Sprinkler Systems.

It was particularly important to ensure the sprinkler system was sympathetic to the building. The visual impact of the installation was to be minimal, and was to take into consideration the following (Cochran et al, 1999):

- sprinkler control valves and pump, if necessary, to be placed in visually discreet positions, approved by the architect

- sprinkler heads to be placed in positions carefully chosen in relation to the architectural form and detail of the building so as to minimise their visual impact. Pipework to be run in cavities wherever possible. Where it is not possible, pipework to be run in discreet and carefully chosen places to minimise their visual impact. All sprinkler heads and pipe runs will be approved by the architect.

The system would have to meet all the specifications of NZS 4541:1996, including commissioning and annual testing and maintenance.

9. Building Code regulations

Building Code regulations are in place to set minimum standards for the safety of occupants and users, and in some cases for the protection of property. Internationally there are differing approaches and those for New Zealand, United States of America, and Australia have been reviewed here.

9.1 New Zealand

The provisions in the New Zealand Building Code (NZBC)are aimed at life safety and the protection of other property. They are not primarily intended to prevent or limit property loss of the building or its contents.

Under the NZBC Approved Documents fundamental to the design of a fire safety system for any building is the classification of the purpose group for that building. In the case of traditional Māori buildings, their multi-functional use makes it difficult to assign a single purpose group. For example, the main marae building, the wharenui, can be used for events from meetings to eating to sleeping.

To compensate for the variability of use, the NZBC Acceptable Solutions (BIA, 2001) require a 'worst-case' scenario to be assessed. The 'worst-case' classifies the wharenui as a *crowd* and *sleeping* occupancy, assigning purpose group SA (Paragraph 6.7.9, Acceptable Solution C/AS1).

Wharenui are required to be separate firecells, having a fire resistance rating (FRR) of no less than 30/30/30 if unsprinklered, or 15/15/15 if sprinklered. If the wharenui is not sprinklered, the firecell is not permitted to contain other purpose groups, except for sanitary facilities.

The maximum number of people permitted to sleep in a wharenui is limited, as defined by paragraph 6.7.2 of Acceptable Solution C/AS1 (BIA, 2001). No more than 40 bed spaces are permitted if the building is unsprinklered, or 160 bed spaces if an automatic fire sprinkler system with smoke detectors and manual call points is installed.

There are requirements for interior surface finishes to inhibit fire spread. These requirements include limits on Smoke Development Index (SDI) and Spread of Flame Index (SFI) as determined by the Standard AS/NZS 1530.3 (SA 1999), Methods for fire tests on building materials, components and structures; Part 3: Simultaneous determination of ignitability, flame propagation, heat release and smoke release.

For wall and ceiling linings in exitways of wharenui, the limiting requirements are SFI=0 and SDI≤3. Exitways are not commonly used in wharenui since open paths generally lead to final exits and outside. Sleeping and assembly areas must have SFI≤2 and SDI≤5. Passageways, corridors and stairways not being part of an exitway require SFI≤7 and SDI≤5. Flooring and coverings in exitways must be non-combustible, or have low radius of effects of ignition. Solid untreated timber when tested to AS/NZS 1530.3 (1999) typically would achieve SFI > 2, although fire retardant treated timber may be able to comply, and SDI in the range 3 to 5 (FCRC 1998). The types of material used in marae including native timbers, toetoe and tukutuku panels would therefore not comply.

Tables 3.2 and 3.3 in the Acceptable Solutions C/AS1 (BIA 2001) identify the permitted width of escape routes and escape path travel distances respectively for each purpose group. A building serving the same function as a wharenui but with complying surface finishes for wall and ceiling linings would be permitted to have a minimum escape width of 850 mm, a dead-end open path length not exceeding 18m, and a total open path not exceeding 45m. And, if the occupant load is greater than 50, two or more exits are required. The Acceptable Solutions recognise that wharenui surface finishes do not meet the SFI and SDI requirements, and have made specific modifications to compensate. For means of escape from wharenui, the maximum permitted length of open path is required to be halved (Paragraph 3.4.2) and the escape route widths are required to be doubled (Paragraph 3.3.2).

Table 1: Escape route width and path lengths

	Escape width (horizontal travel) (mm)	Dead end open path length (m)	Total open path length (m)
Fully compliant building	850 per exit	18	45
Wharenui option	1700 per exit	9	22.5

The path lengths can be increased where fire detection and or suppression systems are present. For firecells housing sleeping purpose groups, the increases range from 10% where heat detectors are installed to 50% for each sprinkler and smoke detector where these are present.

9.2 United States

The National Fire Protection Association (NFPA) in the United States has published two standards which are in particular reference to fire protection of cultural resources and historic buildings. Clauses from these two standards which are relevant to the fire protection of traditional Māori buildings are outlined in the following sections (refer Sections 9.2.1 and 9.2.2).

9.2.1 NFPA 909 Code for the Protection of Cultural Resources (NFPA 909 (2001))

This code, by the NFPA, applies to culturally significant structures and to their contents. Such structures include – but are not limited to – buildings that store or display museum or library collections, historic buildings and places of worship. These structures also include spaces within other buildings used for such culturally significant purposes.

The code pertains to:

1. New buildings or portions of buildings used as a cultural property occupancy.

2. Additions made to a cultural property occupancy.

3. Alterations, modernisations or renovations of existing occupancies.

4. Existing buildings, or portions thereof, upon change of occupancy to a cultural property occupancy.

Cultural properties are defined by this code as '*buildings, structures or sites, or portions thereof, that are culturally significant, or that house culturally significant collections. Such properties include, but are not limited to, museums, libraries, historic structures, and places of worship.*'

An historic building is '*a building which is designated by a local, regional, or national jurisdiction as having historical, architectural, or cultural significance.*'

An historic structure is defined as '*a building, such as a bridge, lighthouse, or ship, which is designated by a local, regional or national jurisdiction as having historical, architectural, or cultural significance.*'

The code covers and considers:

a) Fire emergency planning

b) Fire prevention

c) New construction, alterations and renovations

d) Fire precautions during alterations and renovations

e) Inspection, testing and maintenance

f) Historic structures and sites

g) Museums and museum collections

h) Libraries and library collections

i) Places of worship

The following outlines considerations in NFPA 909 which are applicable to traditional Māori buildings.

Fire emergency planning

Fire emergency planning involves establishing and maintaining plans and programs to protect against the disastrous effects of fire. The fire safety goals or objectives adopted shall reflect the level of loss and interruption of service to the client community that those responsible for the cultural property are willing to accept as a result of a fire.

The fire emergency plan is developed as a result of a fire hazard survey which determines existing and potential fire hazards. The fire hazards must be evaluated and classified for their severity and the difficulty and cost of abating them. The fire hazard survey must include the following (NFPA, 2001):

1. *Identification of the cultural properties and special hazards and the creation of an action plan to minimise, eliminate, or protect against each of those hazards.*

2. *Identification of those fire risks and means-of-egress problems created by special events, and the creation of an internal process and action plan to minimise or eliminate those potential threats for each event.*

3. *Recognition that public visitation will increase during special events, celebration, and special exhibitions, and the creation of provisions for identifying and taking immediate action to prevent numbers of visitors from exceeding building and means-of-egress capabilities.*

4. *Recognition that temporary or special exhibitions will result in special fire protection risks and means-of-egress problems and compromise existing fire protection systems, and the creation of an action plan for preventing such problems and implementing immediate corrective actions if problems arise later.*

The fire protection plan developed is required to have a fire safety log which includes (NFPA, 2001):

1. *Training of staff and volunteers, including fire evacuation drills and use of portable fire extinguishers.*

2. *Testing, inspection and maintenance reports for all fire safety equipment and systems, including records of actions taken to correct deficiencies.*

3. *As-built plans, specifications, wiring and layout diagrams, and acceptance test reports for all fire protection systems (e.g. fire detection and alarm systems, automatic fire suppression systems).*

4. *The facility's fire protection plan.*

5. *The facility's emergency plan.*

6. *Inspection reports by local code enforcement officials, the authority having jurisdiction, local fire service officials, and insurance loss-control representatives, including records of actions taken to correct deficiencies identified during each inspection.*

7. *Fire protection systems actuation and alarm reports complete with the cause of the alarm or activation, response, and corrective action(s) taken.*

8. *Full reports, including cause, extent of damage, response and recovery of all fire incidents.*

The NFPA (2001) code requires cultural properties to implement precautions to prevent arson.

A salvage plan must be prepared in cooperation with the fire department, appropriate building staff, police and insurance representatives. This plan must be updated annually and include the following (NFPA, 2001):

1. *Procedures to identify and prioritise collections and other valuable materials in accordance with the facility's policy.*

2. *A list of salvage equipment suppliers (e.g. for pumps, freezing equipment storage facilities and so forth) and tradespeople.*

3. *A current list of disaster recovery specialists for damaged fine arts, collections, and archives, such as conservators from museums, archives, and other cultural properties willing to lend mutual aid assistance.*

4. *A list of people assigned to assist with salvage operations, including staff to deal with the press, fire authorities, police, and authorities that can restrict entry following a fire of suspicious origin.*

5. *Measures to maintain up-to-date copies of important documents in a secure, off-site location.*

6. *Procedures to identify and handle hazardous materials such as asbestos or PCPs, that can cause a health hazard or contaminate the structure or contents after a fire. These procedures shall include impoundment of fire-fighting water where it poses a hazard to the environment.*

Fire safety training is a significant contributor to the fire safety plan for the building. Annual fire drills are required to reinforce the training. There are requirements for building staff to be:

- practised in evacuation drills
- familiar with the fire protection plan
- familiar with the salvage plan
- familiar with the fire protection and detection systems in the building
- trained in the use of portable fire extinguishers.

A fire prevention strategy is an important part of the fire safety plan, recommended for the protection of cultural resources. Requirements apply to:

- decorations – decorative materials used for special events must be non-combustible or treated with a fire-retardant coating

- fire spread control – interior doors must be kept closed when the building is not occupied

- housekeeping – means of egress are to be free of items causing obstruction or items, such as rubbish containers, which potentially add to the fuel load. Strict requirements relate to the disposal of rubbish

- smoking – cultural buildings are to be smoke-free unless there is a designated smoking area which meets strict criteria, including the area being physically separated from the rest of the building by construction having a minimum one hour fire-resistance rating and supply of fire extinguishers

- hot work – any work using open flame devices (e.g. soldering, welding) requires a permit and supervision

- open flames – the authority having jurisdiction is required to approve the use of open flame and flame-production devices (e.g. candles, oil lamps, kilns, fireplaces). Strict precautions safeguard the use of open flames including, for example, candles kept a minimum of 1.2 m from combustible window treatments and wall or ceiling hangings, open flames and flame-producing devices must be monitored constantly by a trained person.

- chimneys – must be in accordance with NFPA 211, shall be lined, provided with a spark arrestor, inspected and cleaned annually and be maintained in good working order

- electrical hazards – electrical wiring, temporary wiring and communication cabling must be installed and maintained in accordance with the appropriate NFPA standard.

New construction, alterations and renovations affect the fire safety system for the building. The following outline fire requirements from NFPA 909 which are of particular relevance to new construction, alterations and renovations to traditional Māori buildings and include:

- fire protection, detection and alarm systems installed in the new or altered construction shall meet code requirements

- unlisted combustible roof coverings must be treated with an approved fire-retardant coating

- interior finishes shall be selected to prevent flames from spreading rapidly or generating dangerous amounts of smoke and toxic products of combustion. Interior finish materials shall comply with the requirements of NFPA 101 Life Safety Code.

For new construction, alterations and renovations of windowless buildings, NFPA 909 has the following requirements:

- windowless buildings shall be provided with knockout panels to allow fire department access to the building

- an automatic fire suppression system shall be installed in accordance with the applicable NFPA standard(s) or code(s)

- approved heat and smoke venting shall be installed

- provisions shall be made for removal of accumulated water from fire-fighting operations.

Appendix A of NFPA 909 notes: *'Some cultural resource institutions have been reluctant to install automatic sprinklers for fear of water damage to their collections. Yet, in actual fires the most extensive water damage has resulted from fire department operations with hose lines. Sprinkler protection minimises water damage by placing a small amount of water directly on the fire and alerting the fire department at the same time.'*

9.2.2 NFPA 914 Code for Fire Protection of Historic Structures (NFPA 914, 2001)

This code '*describes fire safety requirements of the protection of historic structures and for those who operate, use, or visit them. It covers ongoing operations, renovation and restoration and acknowledges the need to preserve historic character.*'

The purpose of the code is to '*provide fire protection and life safety systems in historic buildings while protecting the elements, spaces and features that make these structures historically or architecturally significant*'.

'*The historic preservation goal of this code is to provide a reasonable level of protection against damage to and loss of historic structures, their unique characteristics and their contents as follows:*

1. *Minimise damage to historic structures or materials from fire and fire suppression.*
2. *Maintain and preserve original space configurations of historic buildings.*
3. *Minimise alteration, destruction or loss of historic fabric design.*'

The scope, purpose and goal of NFPA 914 are appropriate for applying to the development of fire protection strategies for traditional Māori buildings.

The NFPA 914 code defines an historic building as '*a building that is designated or deemed eligible for such designation, by a local, regional or national jurisdiction as having historical, architectural or cultural significance*'.

Other definitions which define the scope of the NFPA 914 code include:

1. Historic fabric – original or added building or construction materials, features and finishes that existed during the period that is deemed to be most architecturally or historically significant, or both.

2. Historic preservation – a generic term that encompasses all aspects of the professional and public concern related to the maintenance of an historic structure, site or element in its current condition, as originally constructed, or with the additions and alterations determined to have acquired significance over time.

3. Historic site – a place, often with associated structures, having historic significance.

4. Historic structure – a building, bridge, lighthouse, monument, pier, vessel or other construction that is designated or that is deemed eligible for such designation by a local, regional or national jurisdiction as having historical, architectural or cultural significance.

Clauses from NFPA 914 are particularly applicable to the fire protection of traditional Māori buildings. A general process has been developed to assess the fire protection requirements for an historic building. The process involves:

1. Assigning a process team to oversee the application of the code to the historic building.

2. A detailed assessment or survey of the fire safety features and the historic integrity of the structure, site or both.

3. Identification of historic elements, spaces and features.

4. Prioritisation of historic elements, spaces and features.

5. Identification of fire safety issues.

6. Plan of fire safety options to address the issues.

7. Implementation of the appropriate system.

8. Audit of fire safety system.

The code highlights the importance of fire precautions during construction, repair and alterations to the historic building. Inspection, testing and maintenance criteria are as for the standard requirements for the particular fire protection system.

Chapter 10 of the code specifies considerations when special events are held in the historic structure. These considerations include requirements for:

- **occupant loading** – it shall be ensured that the number of occupants admitted to the building is monitored and controlled so that the occupant load does not exceed the permitted maximum

- **means of egress** – as for the normal operation of the building with the addition of an approved evacuation plan

- **cooking** – a fire extinguisher shall be located by temporary cooking/warming facilities

- **fireworks** – in controlled area away from the building

- **combustibles** – draperies and decorative materials used inside the building, tents and canopies shall be non-combustible or certified as having been treated with an approved fire-retardant coating

- **Electrical equipment.**

9.3 Australia

Work by the Fire Code Reform Centre in Project 2A (FCRC, 1998) found that wall and ceiling lining materials can be a major contributor to fatalities in fires in buildings, and that there was a need to control the fire behaviour of wall and ceiling linings in buildings to keep loss of life at an acceptable level. The report concluded that the real fire performance of lining materials can be assessed for regulatory purposes by considering time to flashover in the ISO 9705 full-scale room test. Further, as an alternative to carrying out full-scale room tests, relationships existed to allow data from the small-scale cone calorimeter test to be used in predicting flashover in the ISO room. Time to flashover is defined as the time taken for the heat release rate to reach 1 MW from the ISO room. This method for the classification of linings has subsequently been adopted by Amendment 13 to the Building Code of Australia (BCA 96).

BCA 96 Specification C1.10a states – 'A material used as a finish, surface, lining or attachment to a wall or ceiling must be a Group 1, Group 2 or Group 3 material used in accordance with Table 2 and for buildings not fitted with a sprinkler system complying with specification E1.5, have-

a. a *smoke growth rate* index not more than 100; or

b. an *average specific extinction area* less than 250 m^2/kg.

The classification can be made on the basis of testing carried out at either full-scale (ISO 9705) with the classification made directly from the time to flashover, or at small-scale in the cone calorimeter using the test results in conjunction with a mathematical model (Specification A2.4) to predict the time to flashover in the ISO 9705 room fire test. The wall and ceiling lining materials are then grouped into one of four categories based on this time to flashover parameter, with 1 being the best and 4 the worst, as follows:

(i) A Group 1 material is one that does not reach flashover when exposed to 100 kW for 600 seconds followed by exposure to 300 kW for 600 seconds.

(ii) A Group 2 material is one that reaches flashover following exposure to 300 kW for 600 seconds after not reaching flashover when exposed to 100 kW for 600 seconds.

(iii) A Group 3 material is one that reaches flashover in more than 120 seconds but less than 600 seconds when exposed to 100 kW.

(iv) A Group 4 material is one that reaches flashover in less than 120 seconds when exposed to 100 kW.

10. Experimental work

The experimental phase of this study was developed to provide data on the fire performance of traditional wall and ceiling lining materials used in wharenui, and to improve our ability to model the fire development and from that predict the life safety characteristics in such buildings. To achieve reliable fire modelling, it has to be based on accurate fire development test data for the constituent materials in their specific configuration.

The test programme consisted of a single full-scale ISO 9705 test to determine the overall fire performance of the wall and ceiling lining materials in combination. Further testing comprised of an extensive series of small-scale tests carried out using the cone calorimeter to determine the fire performance properties for each of the individual construction materials and panels.

The full-scale ISO 9705 room tests the wall and ceiling linings at a realistic scale and configuration. The sampling equipment provides very similar data to that from the cone calorimeter and includes the heat release rate, total heat released and smoke developed measurements. These parameters accurately describe the fire development and can be used in fire modelling. Previously the early fire hazard test AS/NZS 1530.3 has been used to determine the performance of wall and ceiling linings. The AS/NZS 1530.3 test does not consider the orientation of the linings or the relationship between the wall and ceiling, and the resulting indices do not describe the fire development. Although New Zealand continues with AS/NZS 1530.3, Australia has adopted calorimeter-based fire tests, replacing the early fire hazard test for the regulatory assessment of wall and ceiling linings.

10.1 Full-scale experiment

10.1.1 Methodology

A full-scale test monitoring the combustion behaviour of traditional wall and ceiling linings was undertaken at the BRANZ fire laboratory to the specifications of ISO 9705 (ISO, 1993). The ISO 9705 test room comprises a lightweight concrete room measuring 2.4 m x 3.6 m in plan by 2.4 m high, with a 0.8 m x 2.0 m door opening in one of the short walls. The room is then lined with the test materials and a small gas burner is located on the floor in contact with the wall linings in one of the corners opposite the door. The burner provides the ignition source and gas is supplied at a rate to achieve a steady 100 kW output for 10 minutes and then 300 kW for a further 10 minutes.

10.1.2 Construction

Wall and ceiling linings of the standard ISO room were designed to replicate traditional construction (refer to Figure 10-4, Figure 10-5 & Figure 10-6).

Figure 10-1, Figure 10-2 and Figure 10-3 are as-built plans of the construction used for the full-scale test labelling dimensions, materials and the Māori names for each component. The construction is representative of a traditional wharenui with a cavity between the decorative interior and the exterior cladding. In this instance, the cavity is 100 mm, as determined by the dimensions of the framing timber, and it is not insulated.

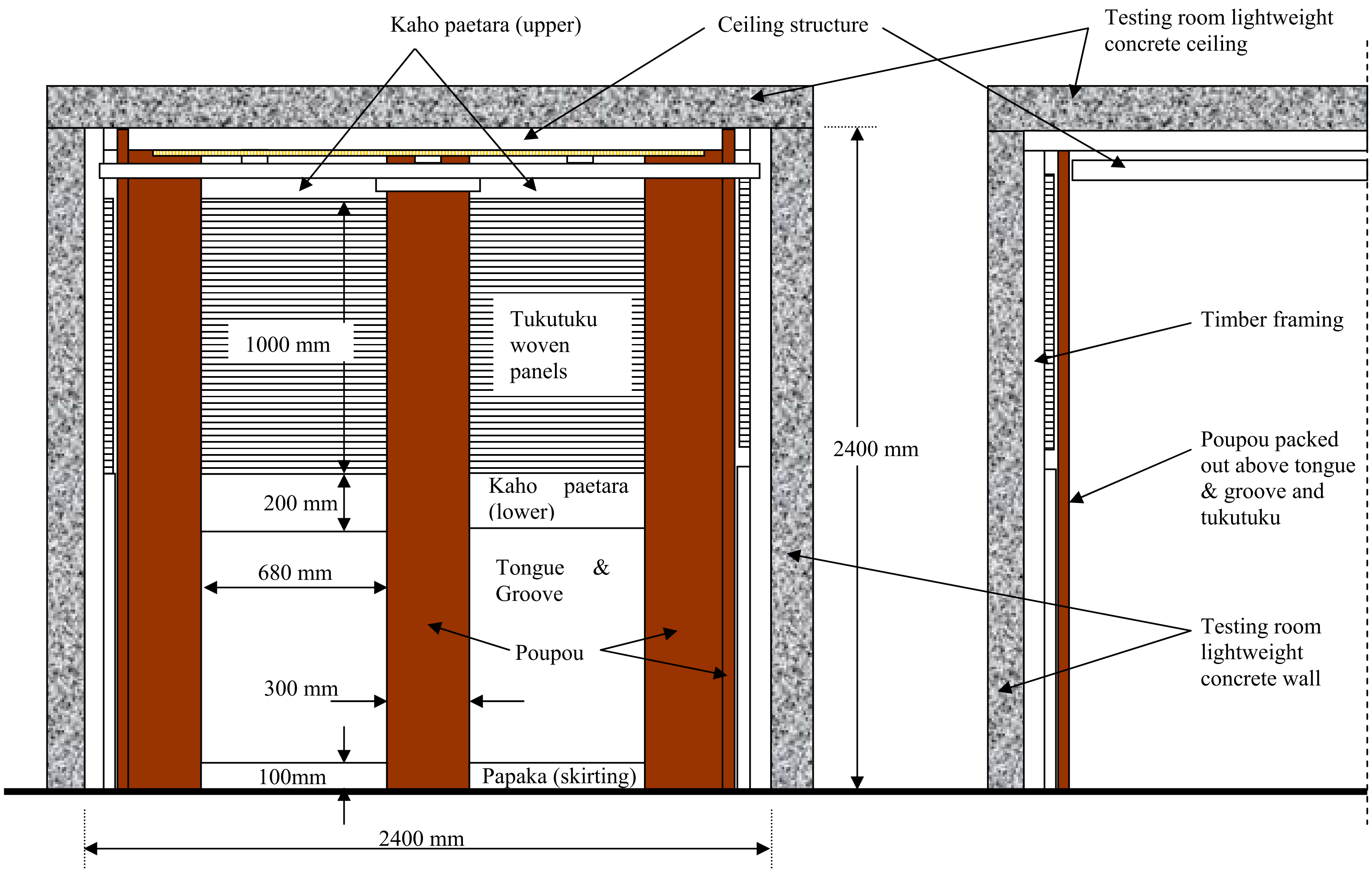

Figure 10-1: End wall construction

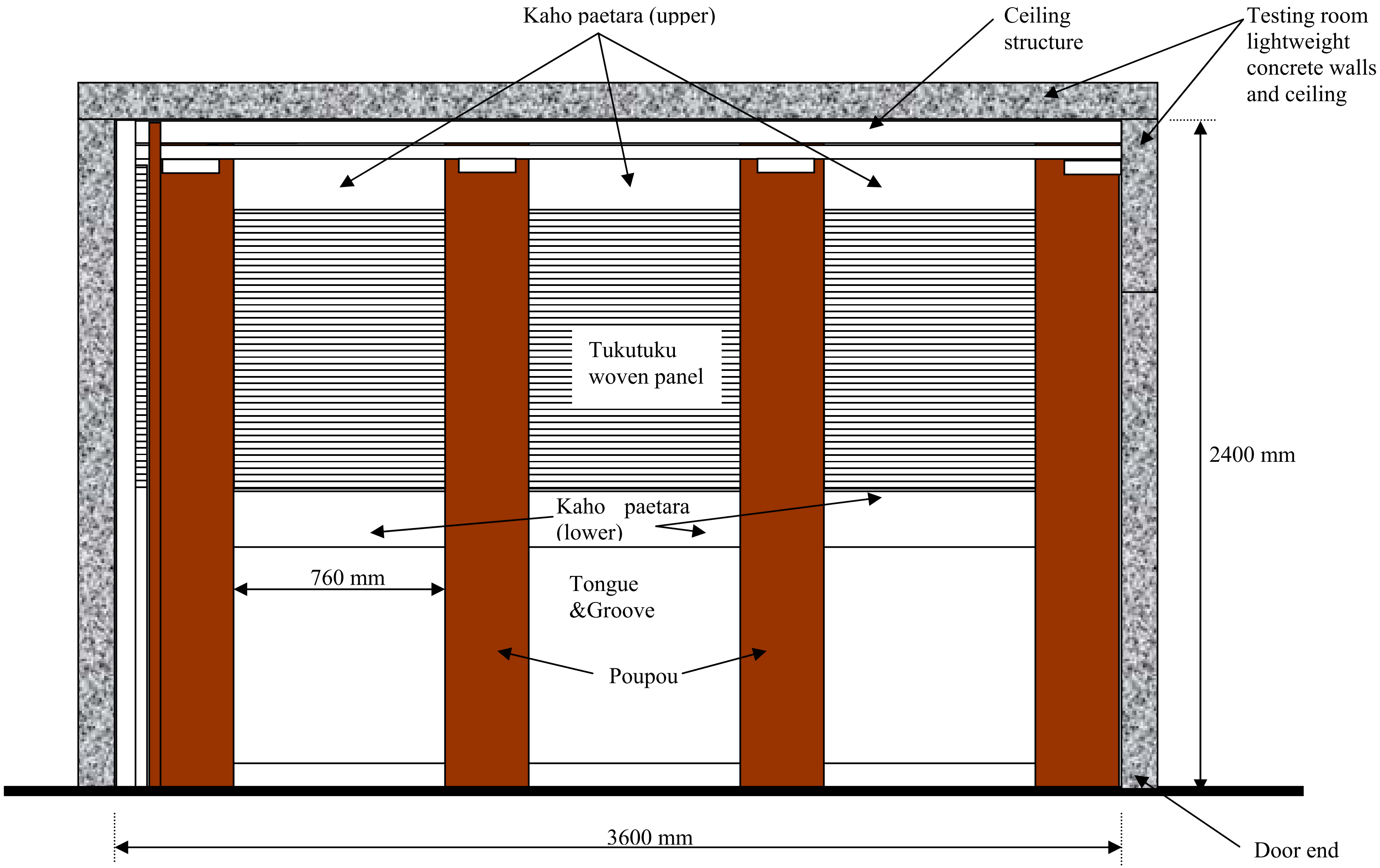

Figure 10-2: Wall construction

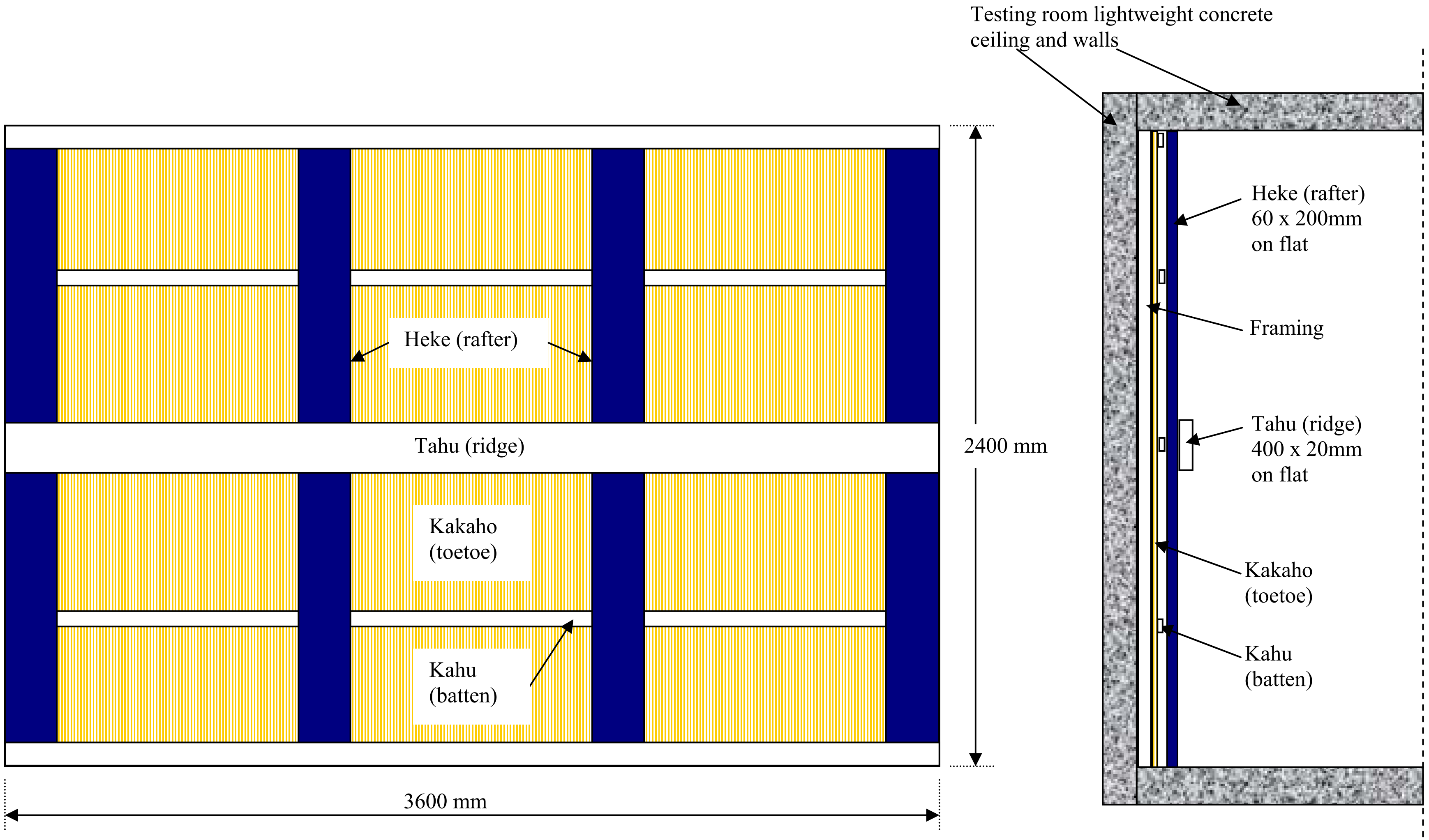

Figure 10-3: Reflected ceiling construction and section

Rimu tongue and groove and woven tukutuku panels lined the walls and the ceiling was lined with kakaho (cut stem of toetoe) suspended on rimu heke (rafters). Posts of totara (300x50) were used to represent carvings (Poupou).

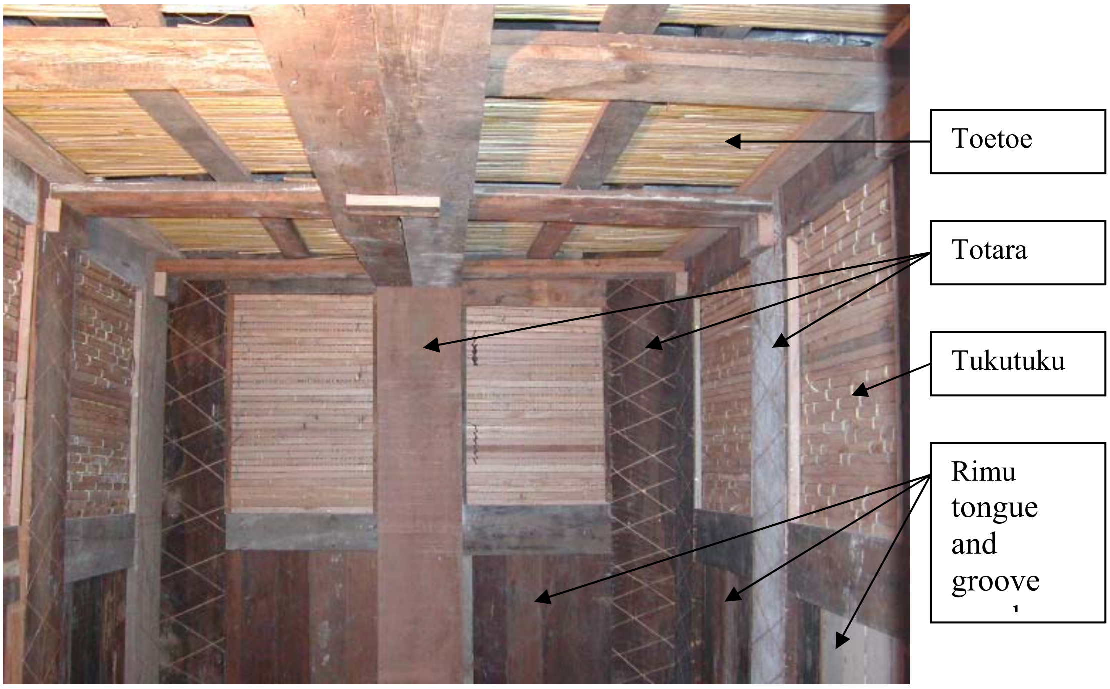

Figure 10-4: Full-scale fire test construction

Each of the tukutuku panels (800 mm x1000 mm) were made of rimu slats (30 mm x 5 mm) and thatched horizontally by flax to stems of toetoe.

Figure 10-5: Traditional wall linings – tongue and groove, tukutuku and replica carvings

The construction differed from the traditional due to the ceiling being flat, not pitched as fundamental to the basic style of wharenui. Testing with a flat ceiling enables results to be compared to those of other wall and ceiling linings similarly tested.

Figure 10-6: Ceiling linings - toetoe and rimu rafters

10.1.3 Materials

The timbers used were recycled, with a moisture content ranging from 10.5% to 12.3% on the day of testing. Where possible, the materials were conditioned to the requirements of the ISO Standard. Conditioning is defined as specimens reaching equilibrium of constant mass in an atmosphere of 50 ± 5% relative humidity at a temperature of 23 ± 2^{o}C (ISO, 1993).

10.1.4 Instrumentation

K-type thermocouples were installed to monitor temperatures in the room, in the wall cavities and on the wall and ceiling linings.

A thermocouple tree was positioned inside the door of the room, 300 mm from the left wall and 200 mm from the end wall as required by the Standard (ISO, 1993).

Additional thermocouples were installed in the wall cavities behind the tukutuku panels and tongue and groove both on the end wall and the right wall.

Thermocouples were added at ceiling height along the right wall and to the underside of the ceiling ridgepole.

Figure 10-7: Fire test 20 seconds after ignition

Figure 10-8: Fire test 90 seconds after ignition

Figure 10-9: Fire test 370 seconds after ignition

Figure 10-10: Fire test conclusion

10.1.5 Results from the full-scale test

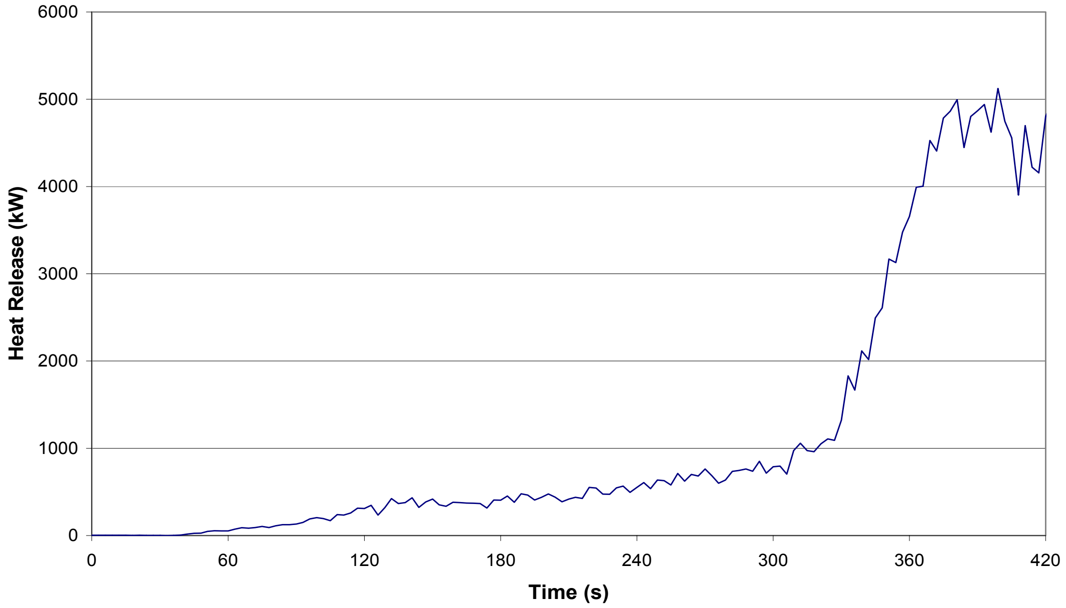

Figure 10-11: Heat release measured in the full-scale test

Flashover is deemed to have occurred in the ISO room when the heat release exceeded 1 MW. In this test, it occurred approximately 320 seconds after ignition.

Figure 10-12 graphs the temperature rise in the room recorded by the thermocouple tree (thermocouples at 0.7, 0.9, 1.3, 1.44, 1.58, 1.71, and 2.18 m above the floor). The temperatures were measured at five second intervals.

Temperatures from the thermocouple tree illustrate the two layered temperature profile through the hot upper layer and cooler lower layer. At flashover, the zones disappeared and a close-to-uniform temperature was recorded through the height of the room (after seven minutes).

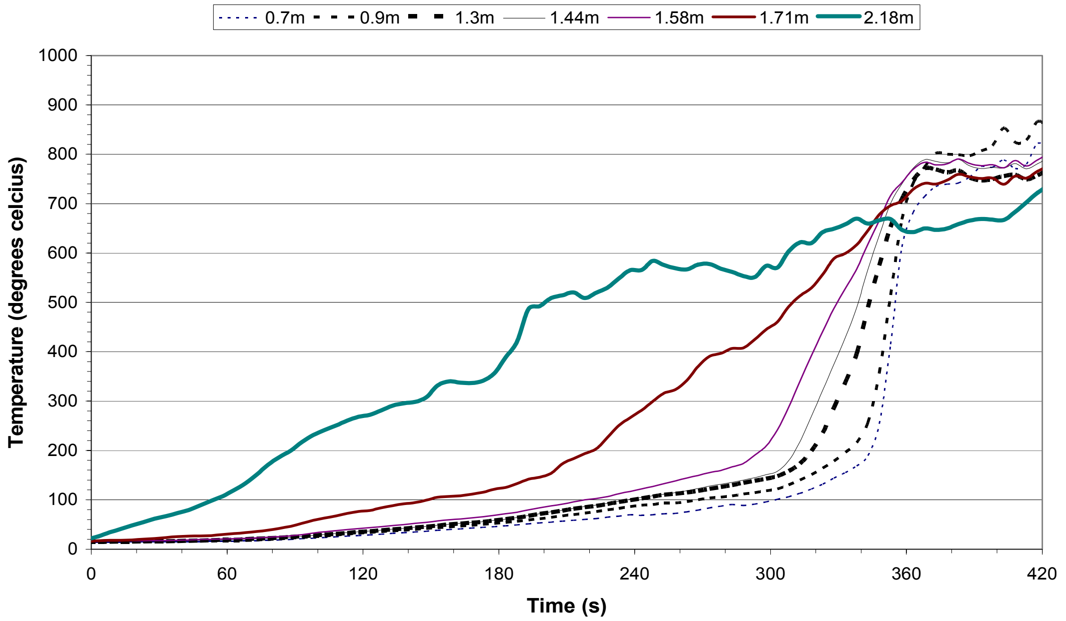

Figure 10-12: Thermocouple tree temperature profile

Results show that temperatures in the cavities were not significantly different from those shown by the thermocouple tree. It was observed that this was due to the rapid flaming of the tukutuku panels. The panels were quick to ignite and fall out of place, exposing the cavity.

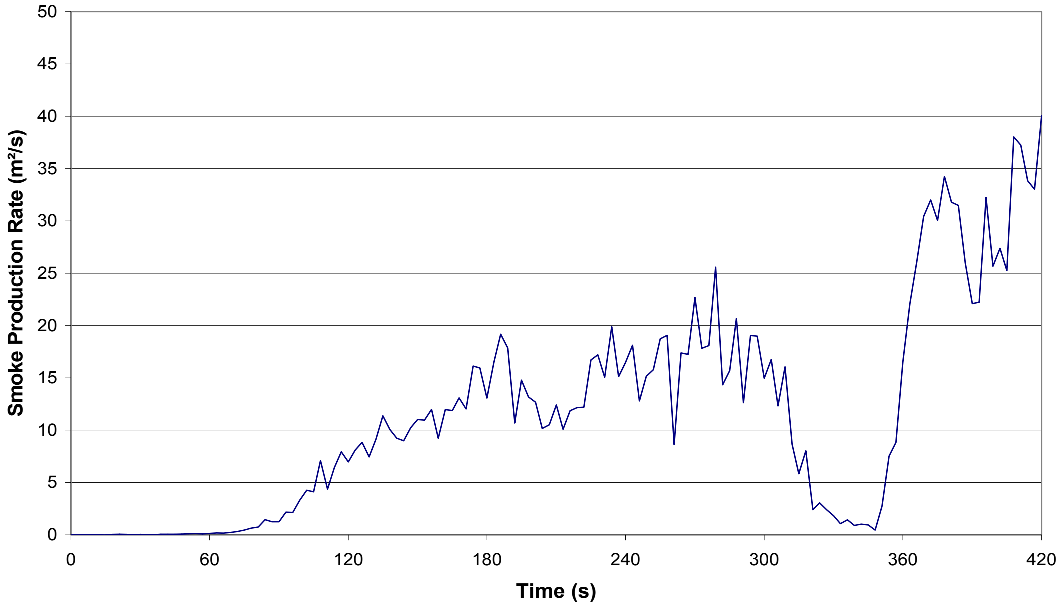

Figure 10-13: Smoke production rate

The smoke production rate steadily increased until flashover occurred, as illustrated in Figure 10-13.

10.1.6 Toxicity

The concentration of oxygen (O_2), carbon dioxide (CO_2), and carbon monoxide (CO) were measured throughout the test and are illustrated in Figure 10-14.

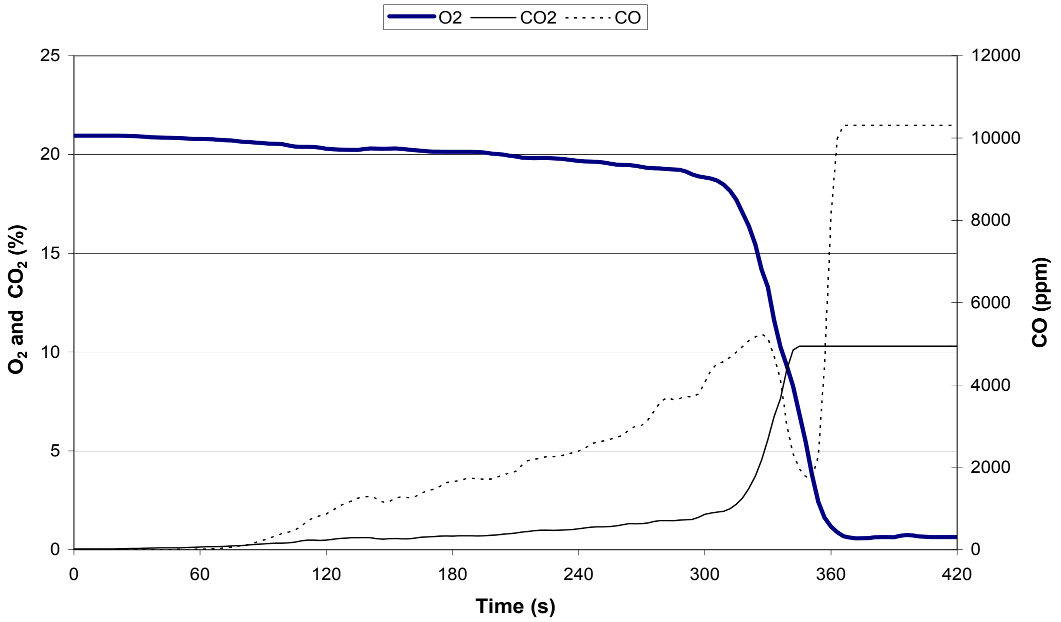

Figure 10-14: Oxygen, carbon dioxide and carbon monoxide concentration levels during the test

10.1.7 Conclusions from full-scale test

Figure 10-15 compares the results of the full-scale ISO test of traditional wharenui construction with that of three other wall and ceiling linings (Mangs et al, 1991):

- FR polystyrene foam (25 mm thick)
- ordinary birch plywood (12 mm thick)
- painted gypsum paper-faced plasterboard (12 mm thick).

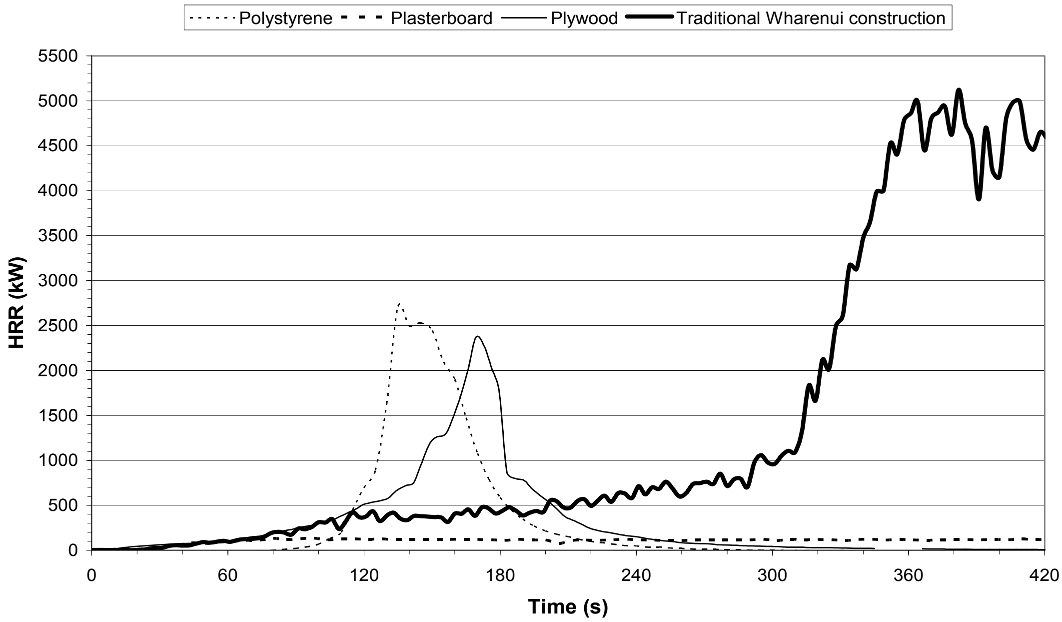

Figure 10-15: Comparison of ISO tests with variations in wall linings

In Figure 10-15, both the polystyrene and plywood lined ISO room tests reached flashover (the time for HRR to reach 1 MW) considerably quicker than the traditional Māori construction lining. The gypsum plasterboard lined room did not reach flashover. An important factor in the performance of the Māori test result is that the fire source, the ISO burner, was in the corner of the room, adjacent to solid totara columns 50 mm thick. It is expected that if the burner had been directly adjacent the tukutuku panel, the rate of fire spread would have been faster.

10.1.8 Classification of linings

The full-scale ISO room test of the traditional Māori construction reached flashover in 320 seconds. Section 9.3 described the classification method now used in Australia for wall and ceiling linings. On the basis of this method, the traditional Māori wall and ceiling linings, would be classified as Group 3.

However, the position of the burner, in the room corner against the 50 mm thick solid totara columns, has influenced the overall performance. It is expected that had the burner been in contact with the tukukuku or toetoe panels, time to flashover would have been less.

Wall and ceiling linings with a similar Group 3 classification include: particleboard, medium-density wood-fibre board and plywood (FCRC 1998, Appendix E).

10.2 Small-scale experiments

A series of small-scale experiments was undertaken to look at the combustion properties of traditional wall and ceiling linings. Samples of the totara, rimu, tukutuku and toetoe were tested in the cone calorimeter in accordance with the test standard ASNZS3837 1998 (Standards Australia & Standards New Zealand 1998).

Each sample was tested using radiant heat fluxes of 25 kW/m^2, 35 kW/m^2 and 50 kW/m^2. For statistical significance, three samples were tested at each flux. The rate of heat release data for the samples tested with the 50 kW/m^2 heat flux is used to assign a classification group for the material as defined by the BCA (ABCB, 1996). The material properties are used as data for input into the computer model BRANZfire, used to simulate fires in a marae wharenui building (refer Section 11).

Table 2: Cone calorimeter results for 50 mm totara*

System ID	*External Heat Flux (kW/m²)*	*Ignition time (s)*	*End of test[a] (s)*	*Total heat evolved [a] (MJ/m²)*	*Peak RHR (kW/m²)*	*60 s average RHR [b] (kW/m²)*	*180 s average RHR [b] (kW/m²)*	*300 s average RHR [b] (kW/m²)*	*Average RHR [c] (kW/m²)*	*Average EHC [a] (MJ/kg)*	*Average SEA [a] (m²/kg)*
1	50	33	1800	136.3	152	135	108	97	77	8.6	26
2	50	27	1800	140.0	141	121	100	94	79	9.4	10
3	50	25	1800	131.9	151	129	107	97	74	8.8	21
Mean		**28**	**1800**	**136.1**	**148**	**128**	**105**	**96**	**77**	**8.9**	**19.0**
± 95%*		**5**	**n/a**	**4.6**	**7**	**8**	**5**	**2**	**3**	**0.5**	**9.3**
1	35	25	1800	71.1	122	107	81	69	40	9.2	25
2	35	39	1800	83.6	134	109	81	69	47	10.3	25
3	35	23	1800	89.0	130	112	84	71	50	10.7	29
Mean		**29**	**1800**	**81.2**	**129**	**109**	**82**	**70**	**46**	**10.7**	**26.3**
± 95%*		**10**	**n/a**	**0.9**	**7**	**3**	**2**	**1**	**6**	**0.9**	**2.6**
1	25	93	1800	41.8	126	94	66	56	24	6.4	112
2	25	73	1800	64.2	121	97	69	58	37	9.7	49
3	25	71	1800	63.0	125	103	75	65	36	9.1	68
Mean		**79**	**1800**	**56.3**	**124**	**98**	**70**	**60**	**32**	**8.4**	**76.3**
± 95%*		**14**	**n/a**	**14.3**	**3**	**5**	**5**	**5**	**8**	**2.0**	**36.6**

* ± 95% confidence interval for preceding replicates.

[a] From start of test; [b] From ignition; [c] From ignition to end of test

EHC = Effective heat of combustion
RHR = Rate of heat release
SEA = Specific extinction area (a measure of smoke)

Table 3: Cone calorimeter results for 20 mm rimu*

System ID	*External Heat Flux (kW/m^2)*	*Ignition time (s)*	*End of test[a] (s)*	*Total heat evolved [a] (MJ/m^2)*	*Peak RHR (kW/m^2)*	*60 s average RHR [b] (kW/m^2)*	*180 s average RHR [b] (kW/m^2)*	*300 s average RHR [b] (kW/m^2)*	*Average RHR [c] (kW/m^2)*	*Average EHC [a] (MJ/kg)*	*Average SEA [a] (m^2/kg)*
1	50	18	1064	93.1	164	138	106	92	89	10.4	202
2	50	22	1132	88.2	146	122	90	79	79	9.7	97
3	50	22	1126	90.6	151	122	93	81	82	9.8	97
Mean		**21**	**1107**	**90.6**	**154**	**127**	**96**	**84**	**83**	**10.0**	**132.0**
± 95%*		**3**	**43**	**2.8**	**11**	**10**	**10**	**8**	**6**	**0.4**	**68.6**
1	35	40	1195	87.0	141	112	81	69	75	10.8	136
2	35	40	1275	77.7	159	108	81	71	62	8.8	114
3	35	37	1345	104.4	151	111	84	73	79	11.3	147
Mean		**39**	**1272**	**89.7**	**150**	**110**	**82**	**71**	**72**	**10.3**	**132.3**
± 95%*		**2**	**85**	**15.3**	**10**	**2**	**2**	**2**	**10**	**1.5**	**19.0**
1	25	67	1345	77.6	124	100	75	64	61	10.1	87
2	25	86	1480	92.2	150	100	71	62	66	10.6	94
3	25	88	1470	95.5	154	106	76	65	69	11	101
Mean		**80**	**1432**	**88.4**	**143**	**102**	**74**	**64**	**65**	**10.6**	**94.0**
± 95%*		**13**	**85**	**10.8**	**18**	**4**	**3**	**2**	**5**	**0.5**	**7.9**

* ± 95% confidence interval for preceding replicates.

[a] From start of test; [b] From ignition; [c] From ignition to end of test

EHC = Effective heat of combustion
RHR = Rate of heat release
SEA = Specific extinction area (a measure of smoke)

Table 4: Cone calorimeter results for tukutuku panel*

System ID	*External Heat Flux (kW/m^2)*	*Ignition time (s)*	*End of test[a] (s)*	*Total heat evolved [a] (MJ/m^2)*	*Peak RHR (kW/m^2)*	*60 s average RHR [b] (kW/m^2)*	*180 s average RHR [b] (kW/m^2)*	*300 s average RHR [b] (kW/m^2)*	*Average RHR [c] (kW/m^2)*	*Average EHC [a] (MJ/kg)*	*Average SEA [a] (m^2/kg)*
1	50	9	339	37.1	171	124	136	118	111	9.8	-
2	50	10	456	40.1	176	110	126	109	89	10.5	-
3	50	11	477	47.9	157	112	122	117	102	11.8	-
Mean		**10**	**424**	**41.7**	**168**	**115**	**128**	**115**	**101**	**10.7**	**-**
± 95%*		**1**	**84**	**6.3**	**11**	**9**	**8**	**6**	**13**	**1.1**	**-**
1	35	30	426	33.1	117	89	96	95	81	9.5	-
2	35	33	504	37.2	136	98	92	96	77	9.5	-
3	35	40	375	28.5	172	94	110	89	83	9.6	-
Mean		**34**	**435**	**32.9**	**142**	**94**	**99**	**93**	**80**	**9.5**	**-**
± 95%*		**6**	**74**	**4.9**	**32**	**5**	**11**	**4**	**3**	**0.1**	**-**
1[++]	*25*	*103*	*633*	*79.6*	*244*	*8*	*76*	*129*	*150*	*19.5*	-
2	25	79	498	25.0	103	76	74	71	58	7.5	-
3	25	74	429	25.4	113	79	83	77	70	8.5	-
Mean		**77**	**464**	**25.2**	**108**	**78**	**79**	**74**	**64**	**8.0**	**-**
± 95%*		**4**	**55**	**0.3**	**8**	**2**	**7**	**5**	**10**	**0.8**	**-**

* ± 95% confidence interval for preceding replicates.

[++] test results not used in calculation of the mean and 95% confidence interval

[a] From start of test; [b] From ignition; [c] From ignition to end of test

EHC = Effective heat of combustion
RHR = Rate of heat release
SEA = Specific extinction area (a measure of smoke)

Table 5: Cone calorimeter results for toetoe*

System ID	*External Heat Flux (kW/m^2)*	*Ignition time (s)*	*End of test[a] (s)*	*Total heat evolved [a] (MJ/m^2)*	*Peak RHR (kW/m^2)*	*60 s average RHR [b] (kW/m^2)*	*180 s average RHR [b] (kW/m^2)*	*300 s average RHR [b] (kW/m^2)*	*Average RHR [c] (kW/m^2)*	*Average EHC [a] (MJ/kg)*	*Average SEA [a] (m^2/kg)*
1	50	7	205	18.0	161	114	96	90	90	10.3	39
2	50	13	200	17.7	174	114	96	93	93	9.5	42
3	50	8	210	18.7	92	112	100	92	92	9.8	38
Mean		**9**	**205**	**18.1**	**142**	**113**	**97**	**92**	**92**	**9.9**	**39.7**
± 95%*		**4**	**6**	**0.6**	**50**	**1**	**3**	**2**	**2**	**0.5**	**2.4**
1	35	50	270	17.9	127	97	90	79	79	9.7	-
2	35	51	235	15.7	142	99	85	84	84	9.3	-
3	35	20	225	16.5	143	80	86	78	78	10.1	-
Mean		**40**	**243**	**16.7**	**137**	**92**	**87**	**80**	**80**	**9.7**	**-**
± 95%*		**20**	**27**	**1.3**	**10**	**12**	**3**	**4**	**4**	**0.5**	**-**
1	25	67	325	19.1	130	96	85	72	72	9.8	10
2	25	76	290	17.1	136	91	87	78	78	9.5	27
3	25	89	295	15.5	131	82	82	74	74	8.6	29
Mean		**77**	**303**	**17.2**	**132**	**90**	**85**	**75**	**75**	**9.3**	**22.0**
± 95%*		**13**	**21**	**2.0**	**4**	**8**	**3**	**3**	**3**	**0.7**	**11.8**

* ± 95% confidence interval for preceding replicates.
[a] From start of test; [b] From ignition; [c] From ignition to end of test
EHC = Effective heat of combustion
RHR = Rate of heat release
SEA = Specific extinction area (a measure of smoke)

10.2.1 Totara

10.2.1.1 Sample description

The totara specimens subjected to cone calorimeter testing measured a nominal 100 mm x 100 mm x 50 mm thick, with a mean density of 560.6 kg/m^3.

10.2.1.2 Results

A summary of the test results for each cone calorimeter test is given in Table 2 together with the mean and 95% confidence interval for each set of replicates tested at the same irradiance level.

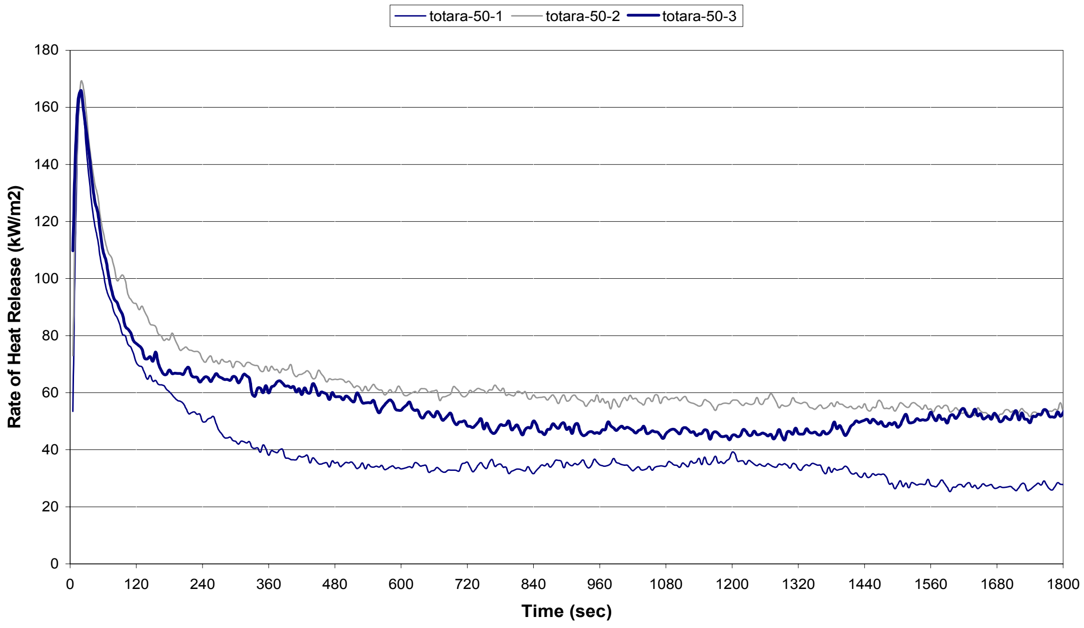

Figure 10-16: Rate of heat release of 50 mm totara (@ 50 kW/m²)

10.2.2 Rimu

10.2.2.1 Sample description

The rimu specimens subjected to cone calorimeter testing measured a nominal 100 mm x 100 mm x 19 mm thick, and a mean density of 564.3 kg/m^3.

10.2.2.2 Results

A summary of the test results for each cone calorimeter test is given in Table 3 together with the mean and 95% confidence interval for each set of replicates tested at the same irradiance level.

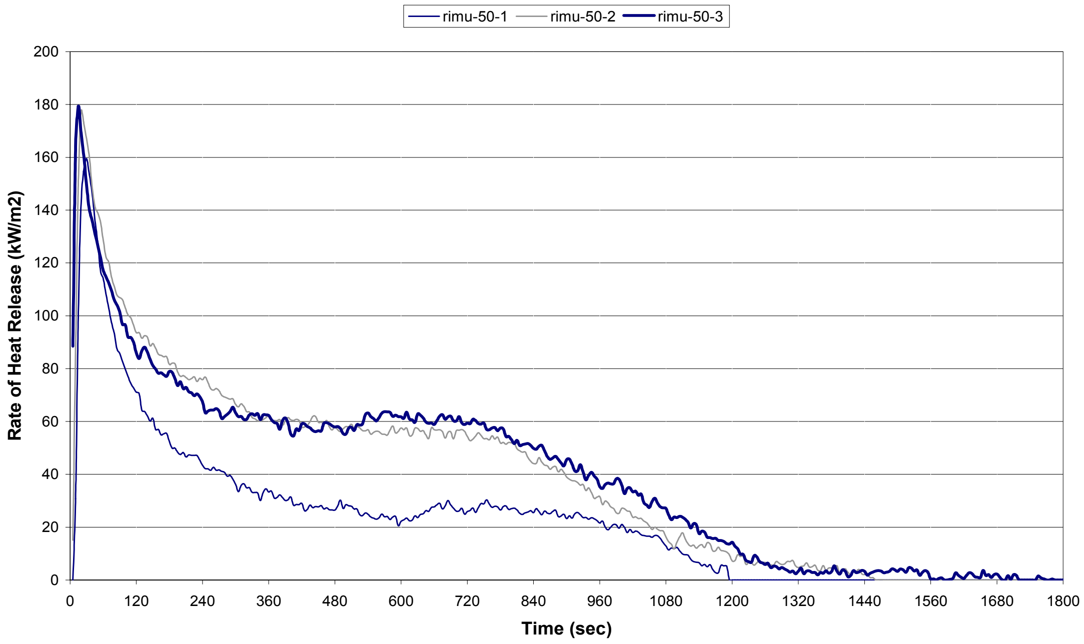

Figure 10-17: Rate of heat release of 50 mm rimu (@ 50 kW/m²)

10.2.3 Tukutuku

10.2.3.1 Sample description

The tukutuku specimens subjected to cone calorimeter testing consisted of 20 mm x 100 mm x 8 mm thick rimu slats thatched horizontally using flax to stems of toetoe orientated perpendicular to the rimu slats. The completed specimen nominally measured 100 mm x 100 mm x 20 mm thick, and a mean density of 204.0 kg/m^3.

10.2.3.2 Results

A summary of the test results for each cone calorimeter test is given in Table 4 together with the mean and 95% confidence interval for each set of replicates tested at the same irradiance level.

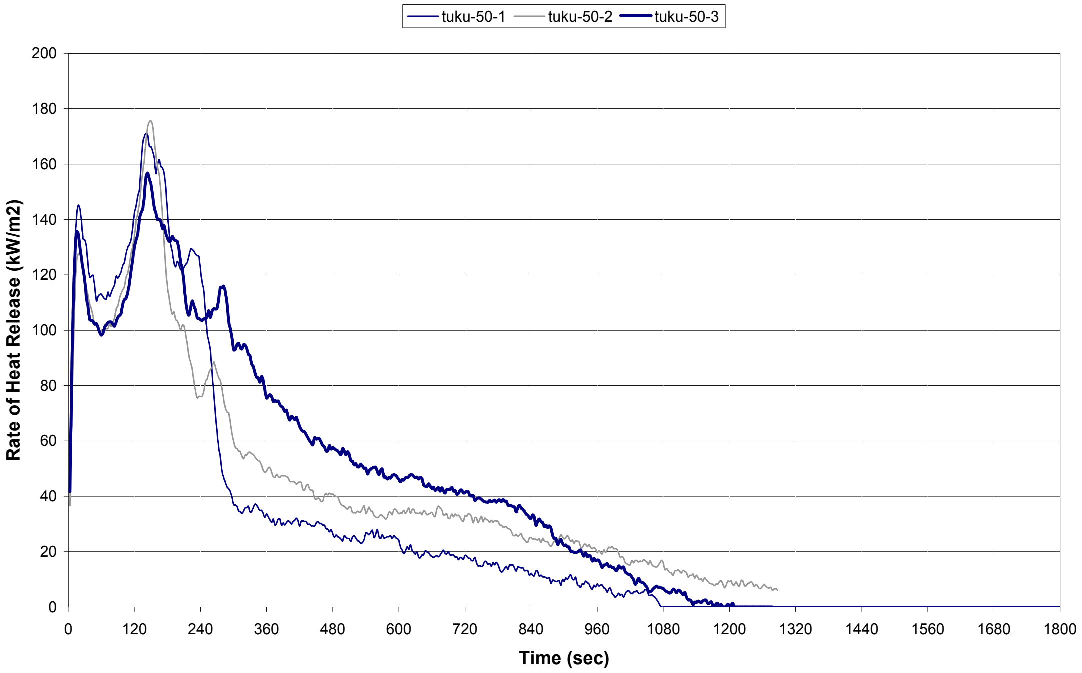

Figure 10-18: Rate of heat release of 50 mm tukutuku (@ 50 kW/m²)

10.2.4 Toetoe

10.2.4.1 Sample description

The toetoe specimens subjected to cone calorimeter testing measured a nominal 100 mm x 100 mm x 11 mm thick, and a mean density of 181.7 kg/m^3.

10.2.4.2 Results

A summary of the test results for each cone calorimeter test is given in Table 5 together with the mean and 95% confidence interval for each set of replicates tested at the same irradiance level.

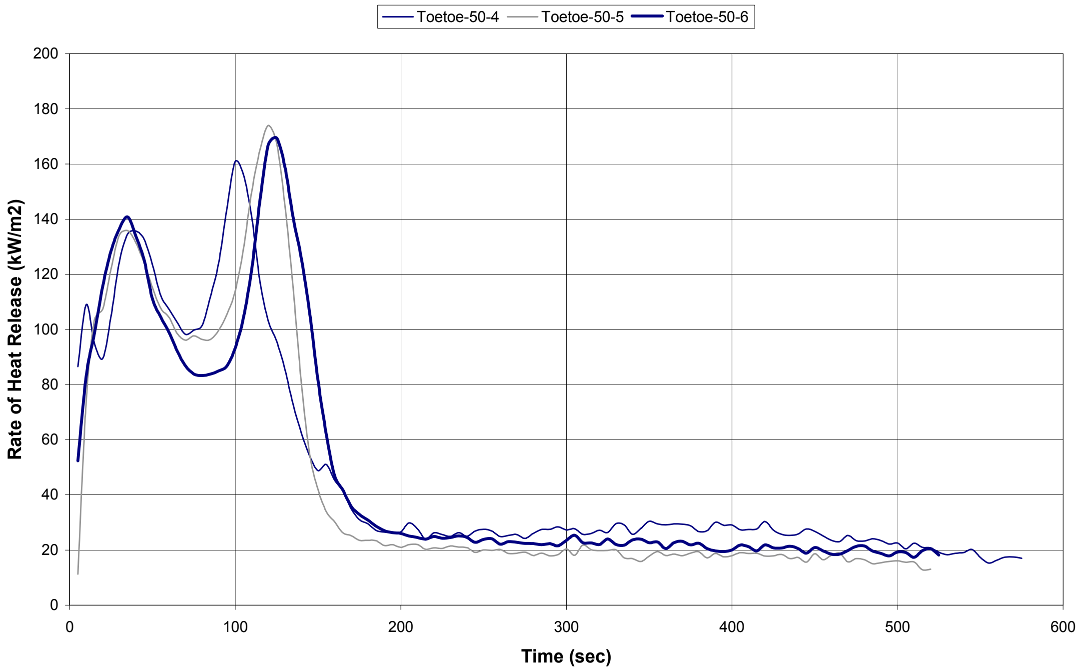

Figure 10-19: Rate of heat release of 50 mm toetoe (@ 50 kW/m²)

10.2.5 Conclusions from small-scale testing

Table 6 summarises the performance of the specimens when applying the BCA Classification of Fire Performance of Wall and Ceiling Lining Materials assessment method (for details of the method refer to Section 9.3, and the full-scale room test classification is given in Section 10.1.8) to the results obtained from cone calorimeter testing using a 50 kW/m^2 heat flux.

Table 6: Summary of small-scale testing

Material	BCA Classification Group			BCA Classification
	Specimen-1	Specimen-2	Specimen-3	
Totara	3	3	3	Group 3
Rimu	3	3	3	Group 3
Tukutuku	4	4	4	Group 4
Toetoe	4	4	4	Group 4

For comparison, standard paper-faced gypsum plasterboard would be expected to achieve a Group 1 classification.

Following this method, it would be reasonable to classify the construction of the ISO 9705 (ISO, 1993) test room lined as a traditional Māori building in Group 4, on the basis of worse case materials. The tukutuku panels on the walls and the toetoe in the ceiling are quick to ignite, however the totara and rimu contribute considerably more in mass terms to the overall fire load of the building.

11. Computer modelling

11.1 Introduction

Computer fire modelling enables the impact of alternative building design proposals on occupant life safety to be analysed without the enormous expense associated with carrying out a full-scale fire test for each modification. It permits multiple scenarios to be modelled, with variations in building dimensions, wall and ceiling lining materials combinations, fire sources, and configuration and dimension of exits and ventilation. The computer fire model used for this analysis was BRANZfire (Wade, 2003).

11.2 Method

11.2.1 BRANZfire

The computer model BRANZfire (Wade, 2003) is a two-zone fire model. A two-zone fire model divides the enclosure into distinct regions, a hot upper zone, and a cooler lower zone. The smoke is assumed to rise to ceiling level to form a hot upper layer of uniform depth and temperature. If there is insufficient flow out of the room the smoke layer descends as the accumulated smoke increases. Each zone is considered homogeneous with properties determined using a mass and energy balance at each time step. The interaction between the two zones mainly takes place through the fire plume. BRANZfire contains many additional features, including a flame spread model which was used in this study.

11.2.2 Fire environments

Two fire environments were analysed: the ISO 9705 (ISO, 1993) standard room and a full-size wharenui building. Analysis of the ISO room was carried out to demonstrate the reliability with which BRANZfire could model the results of the full-scale test (refer Section 10.1). Investigating the fire behaviour in a full-size wharenui was carried out to predict the likely fire environment caused by combustion of traditional construction.

Two types of ignition source are used: ignition from the standard ISO 9705 propane gas burner and ignition of a mattress. The design fires for each are shown in Figure 11-1. The ISO 9705 standard fire was used in modelling the full-scale test and the mattress fire (source BRANZfire database) symbolising a more realistic or likely fire used in the wharenui environment. The modelling did not consider fire spread to other fuel sources in the wharenui other than the wall and ceiling linings.

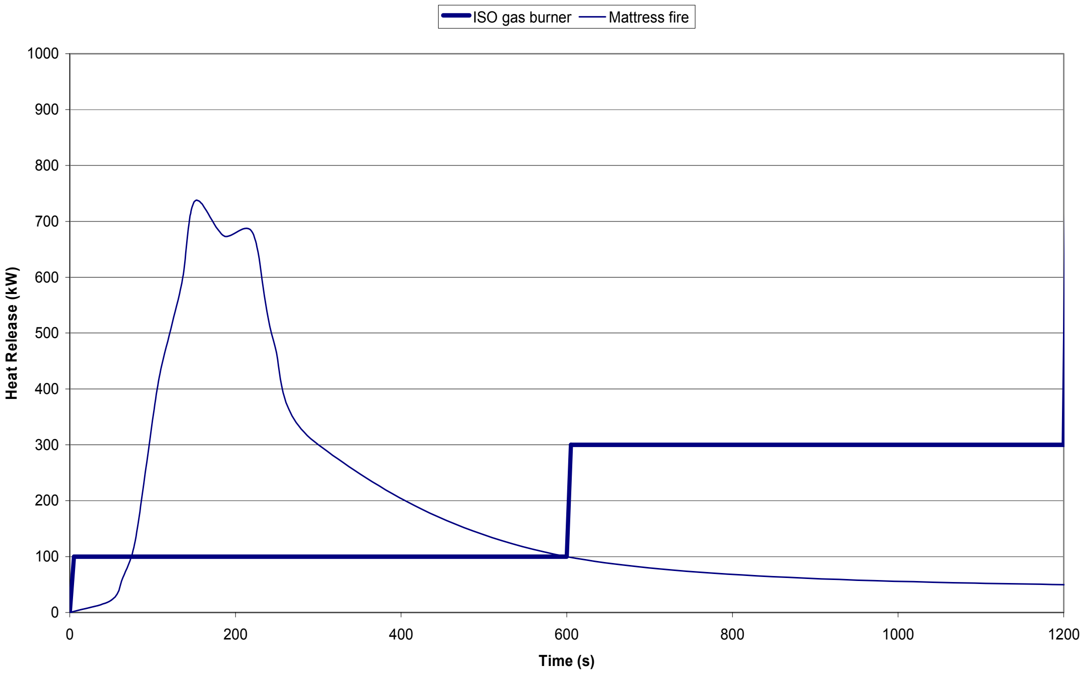

Figure 11-1: ISO 9705 and mattress fire curves used in the BRANZfire modelling

11.2.3 Tenability limits

In an attempt to judge the severity of the fire and its effect on building occupants, the tenability was assessed according to the following criteria and the limits refer to the conditions present in the lower layer (refer Table 7):

Table 7: Tenability limits

Parameter	Tenability limit
Temperature (at 1.8 m above the floor)	>80°C
Fractional effective dose of narcotic gases	>0.1
Fractional effective dose of radiation	>1.0
Visibility (at 1.8 m above the floor)	<10 m

(Sources:, SFPE handbook (*SFPE 1995*), Fire Engineering Guidelines (*FCRC 1996*), Fire Engineering Design Guide (*Buchanan, 1994*))

The toxicity of combustion products is related to the accumulated quantity over exposure time. The fractional effective dose of narcotic gases (FED narcotic) method (SFPE 1995) provides an index value on a scale from 0 to 1, with 1 representing incapacitation of the occupant. The method considers the effects of exposure to CO, CO_2, and the O_2 concentration over the duration of exposure. Typically a FED narcotic level of 0.1 is used for design purposes, providing an additional margin of safety.

The fractional effective dose of radiation (FED radiation) works similarly to FED narcotic, considering the cumulative dose of radiation over time.

Tenability is assumed to be compromised when measurements of each parameter exceed the limits specified in Table 7.

11.3 ISO Room

11.3.1 Modelling input details

Two scenarios were chosen to model the ISO full-scale test: Scenario One with totara lining the walls and Scenario Two with tukutuku lining the walls. The two scenarios were chosen due to limitations of the modelling software allowing only one material to be specified for the wall lining (a different material for the ceiling is permitted). In the full-scale experiment, the gas burner was located in the 'corner' causing the totara to ignite first (refer Section 10). Using the flame spread model in BRANZfire, the 'corner' is the most influential on the early stages of the fire, hence simulating the fire with totara-lined walls. This was then compared to lining the walls with tukutuku panels. The scenarios modelled using BRANZfire were each run for a maximum of 1200 seconds.

11.3.2 Scenarios One and Two

Table 8 describes the input data for the two scenarios.

Table 8: ISO room fire scenarios

Parameter	Scenario One	Scenario Two
Width	2.4 metres	2.4 metres
Length	3.6 metres	3.6 metres
Height	2.4 metres	2.4 metres
Door	0.8 x 2 metres	0.8 x 2 metres
Wall lining	Totara (50 mm)	Tukutuku
Ceiling lining	Toetoe	Toetoe
Floor	Concrete (100 mm)	Concrete (100 mm)
Additional Vents	Nil	Nil
Fire ignition source	100 kW gas burner	100 kW gas burner

11.3.3 Results

The tenability results from modelling the ISO room with solid totara walls and with tukutuku panel walls are summarised in Table 10. The room was deemed to have reached flashover when the heat release exceeded 1 MW (1000 kW), after 320 s for the room lined with totara (Scenario One), and after 120 s when lined with tukutuku panels (Scenario Two). In Figure 11-2, the BRANZfire modelled HRR curves are illustrated, together with the HRR curve from the actual ISO 9705 fire test.

The agreement between the ISO experiment and the all totara-lined walls of Scenario One was found to be relatively good, given that the experiment comprised a mixture of totara and tukutuku on the walls.

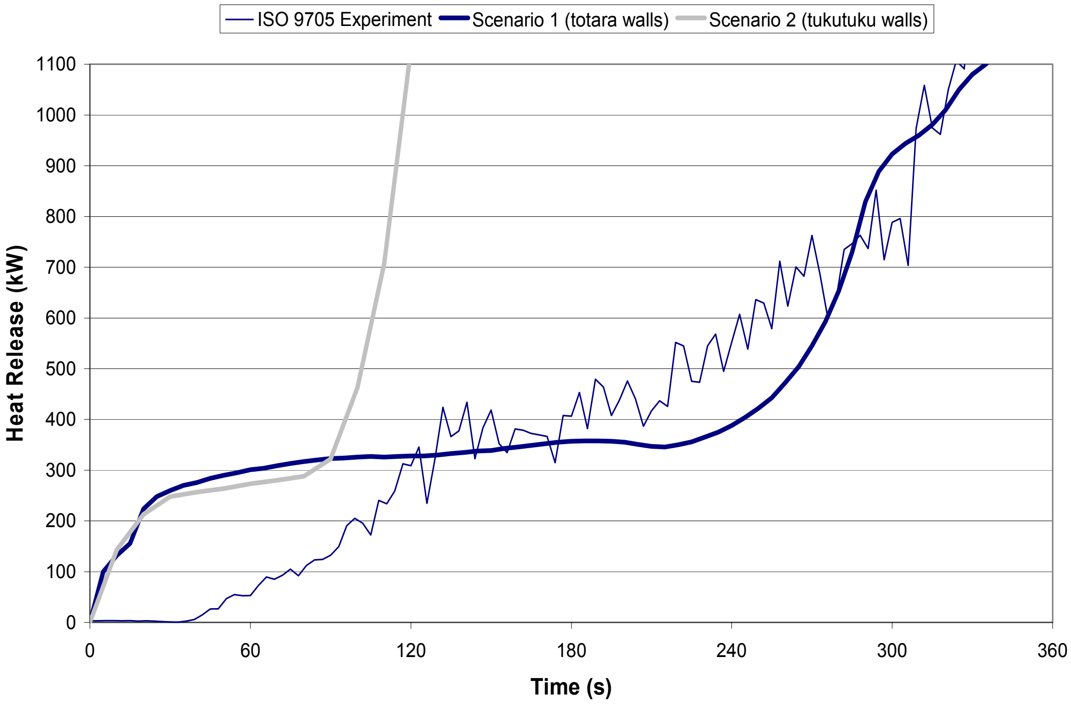

Figure 11-2: Heat release rate curves in the ISO room experiment and the BRANZfire modelled scenarios

11.4 Marae wharenui

It is acknowledged that traditional marae wharenui buildings do not comply with the NZBC Acceptable Solutions for conventional buildings, and specific solutions have been included to accommodate this (refer to section 9.1 for details).

In Section 11.3.3, the ISO 9705 room fire was shown to be satisfactorily modelled using BRANZfire together with the wall and ceiling lining fire performance data from cone calorimeter testing. Based on these results, BRANZfire was applied to model a range of fire scenarios in a full-scale wharenui building with the aim of investigating the life safety implications of various design modifications in an occupied wharenui.

11.4.1 BRANZfire modelling

The design dimensions for the marae wharenui modelled here are based on those of Raukawa Marae in Otaki. The basic form of the building comprises a rectangular plan with relatively low side walls and a pitched roof with an exposed ceiling rising to a centre ridge at approximately 35° above the horizontal.

It is important to note that the fire development rate is determined within BRANZfire on the basis of firstly the height and fire properties of the wall lining, and secondly when the fire reaches the ceiling, on the fire properties of the ceiling lining.

BRANZfire is capable of modelling a sloping ceiling. However, the wall height used in the fire development calculations is taken to be the maximum height (i.e. the height to the centre ridge). Using a sloping ceiling would not replicate the relative wall height-to-ceiling ratio for the development of a fire located in the corner of a real wharenui. It was decided that a flat ceiling would result in a more representative wall height for modelling purposes. The modified dimensions were then a compromise to allow for a realistic fire growth rate calculation and to provide an interior ceiling volume equivalent to that in a real building required for smoke filling and the determination of tenability times. The ceiling is modelled as a flat ceiling positioned at half the height of the actual ridge above the top of the walls. The original dimensions of the building are given in Table 9, alongside the modified dimensions as modelled.

Two ignition sources were modelled, firstly the ISO gas burner consistent with the earlier full-scale fire test presented here, and secondly a mattress fire to present a realistic fire source. Both were located in the corner of the building adjacent to the walls for all scenarios.

Ventilation for the fire compartment was provided by doors to the building of varying width according to the scenario being modelled. Although it is recognised that traditional construction comprises a single door and window, only the door is specified in the model as providing ventilation for the fire. The purpose of the modelling is to estimate the duration that tenable conditions remain for evacuation given a range of scenarios. The point at which the window would break and provide a vent for the fire is likely to occur sometime after the tenability limits have been exceeded. No additional allowance was made for building leakage as this was not considered to be significant in relation to the dimensions of the door opening.

Six further fire scenarios in addition to the two previous scenarios were analysed to investigate the likely fire behaviour in a wharenui:

- Scenario Three – simulates the ISO fire with the burner located in the corner of the room with the totara wall lining as the first structural element to be ignited. The model uses the 'As modelled' wharenui building detailed in Table 9, and includes calculation of flame spread

- Scenario Four – is the same as Scenario Three with tukutuku panels replacing the totara on the walls. The model uses the 'As modelled' wharenui building detailed in Table 9, and includes calculation of flame spread.

- Scenario Five – simulates a realistic fire with a mattress fire located in the corner of the room with totara lining the walls of the corner as in Scenario Three. The model uses the 'As modelled' wharenui building detailed in Table 9, and includes calculation of flame spread.

- Scenario Six – is the same as Scenario Five with tukutuku panels replacing the totara on the walls.

- Scenario Seven – simulates a realistic fire scenario with traditional construction and the number of exits and exit widths meeting the requirements of the NZBC (BIA, 2001). The number of exits required for a building of this size and purpose is two in accordance with Table 3.1 of the NZBC with a purpose group classification of SA and a maximum sleeping occupant load of 40. The traditional construction does not meet the surface finish requirements for SA construction and paragraphs 3.4.2 e) and 3.3.2 h) require the travel distances to be halved and the exit widths doubled.

- Scenario Eight – is a building of the same dimensions and occupancy as Scenarios Five, Six and Seven, but with two complying exits, and fully compliant wall and ceiling linings. The wall and ceiling linings selected are painted plasterboard, meeting the surface finish requirements of the NZBC Acceptable Solutions C/AS1 Table 6.2 (generally timber finishes are not able to meet these requirements).

Table 9: Summary specifications of the marae wharenui building

	Real building	As modelled			
		Scenarios Three, Four	Scenarios Five, Six	Scenario Seven	Scenario Eight
Ignition source		ISO burner	Mattress	Mattress	Mattress
Width (m)	7	7	7	7	7
Length (m)	21	21	21	21	21
Height – side wall (m)	2	3.1	3.1	3.1	3.1
Height – ridge (m)	4.2	3.1	3.1	3.1	3.1
Door (vent) (m) x (m)	Single @ 0.85 x 2	Single @ 0.85 x 2	Single @ 0.85 x 2	Two @ 1.7 x 2	Two @ 0.85 x 2
Window (m) x (m)	1.5 x 1.5	Not included, refer discussion above	Not included, refer discussion above	Not included, refer discussion above	Not included, refer discussion above
Wall lining	Totara and Tukutuku	Three Totara Four Tukutuku	Five Totara Six Tukutuku	Totara	Painted plasterboard
Ceiling lining	Toetoe	Toetoe	Toetoe	Toetoe	Painted plasterboard
Floor	Carpet on timber	Concrete*	Concrete*	Concrete*	Concrete*

* floors and floor coverings are unlikely to become significantly involved in a fire until after flashover. In this modelling only the tenability conditions up to the time of flashover are considered.

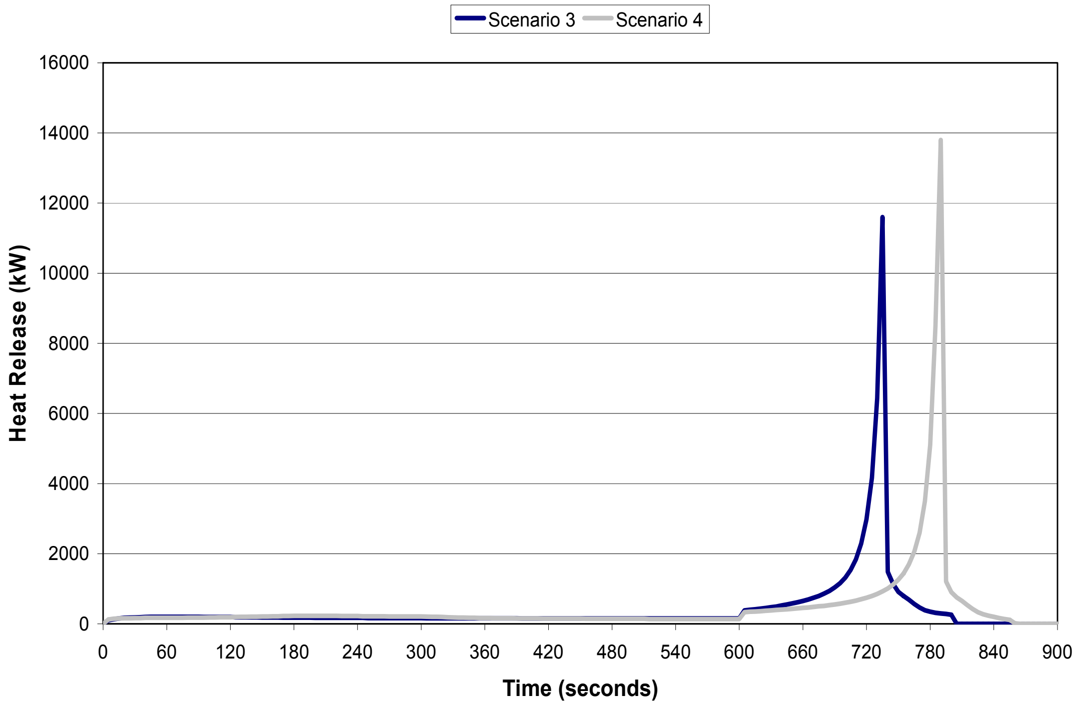

Figure 11-3: Heat release rate curves from the BRANZfire modelled wharenui scenarios with ISO gas burner ignition source

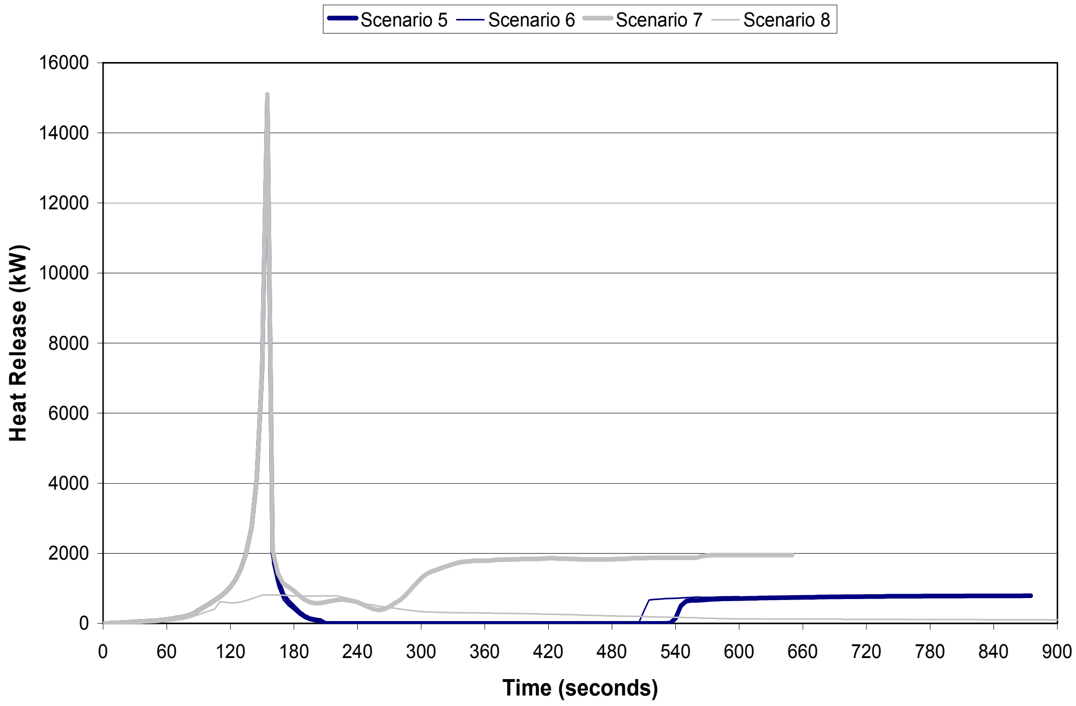

Figure 11-4: Heat release rate curves from the BRANZfire modelled wharenui scenarios with a realistic mattress ignition source

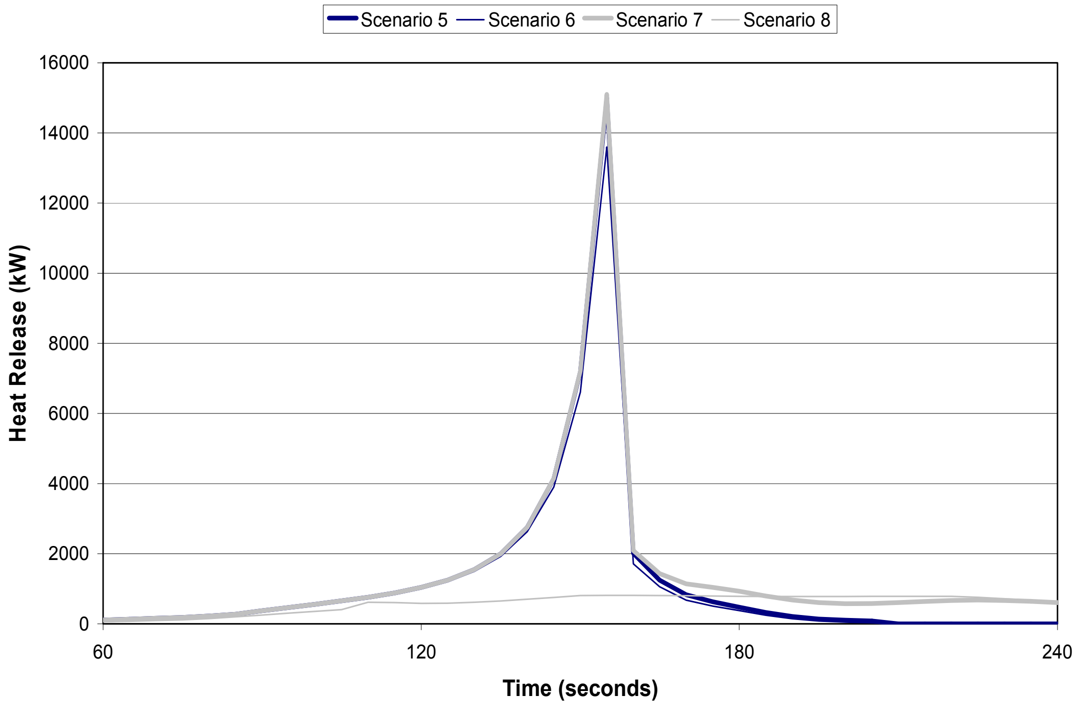

Figure 11-5: Detail of the heat release rate curves in Figure 11-

Table 10: Results – BRANZfire modelling of ISO room fires and wharenui fire scenarios

	Tenability limit	Real fire	BRANZFire modelling							
		ISO Room fire			Marae Wharenui Fire					
		Experimental results	Scenario One	Scenario Two	Scenario Three	Scenario Four	Scenario Five	Scenario Six	Scenario Seven	Scenario Eight
Fire source		ISO Propane gas burner					Mattress fire			
Wall lining		Tukutuku/ Totara	Totara	Tukutuku	Totara	Tukutuku	Totara	Tukutuku	Totara*	Plasterbd
Ceiling lining		Toetoe	Toetoe	Toetoe	Toetoe	Toetoe	Toetoe	Toetoe	Toetoe	Plasterbd
Temperature at 1.8 m	>80°C	320	15	14	701	730	151	152	151	nr
FED - Narcotic	>0.1	327	192	116	738	787	160	161	160	205
FED - Radiation	>1.0	n/a	25	43	700	778	135	158	135	nr
Visibility at 1.8 m	<10 m	n/a	15	14	302	262	113	123	115	125
Time to flashover [+]		320	320	120	740	780	150	150	150	nr

Unless otherwise noted, all figures are times for the tenability limits to be reached given in seconds.

nr ‘not reached’ from ignition to 1200s.

n/a measurements were not able to be recorded during the experiment.

* Totara was only considered on the walls as this had resulted in marginally worse tenability times in the preceding fire Scenarios One to Four.

[+] The time to flashover is dependent on the compartment dimensions. For the experiment and Scenarios One and Two, the time for the fire to reach 1 MW (1000 kW) is used. For the remainder of the scenarios, the time at which the fire becomes ventilation controlled and combustion occurs outside of the room through the doorway has been applied.

11.5 Conclusions from wharenui scale modelling

11.5.1 Comparison of Scenarios Three and Four

Scenarios Three and Four investigate flame spread along the traditional totara and tukutuku wall linings respectively, and their influence on tenability in a realistic wharenui with a single means of escape and the ISO burner ignition source. Modelling found that:

- the tenability limits were reached considerably later than those where the mattress was the initial fire source (refer section 11.5.2), the ISO burner has a less aggressive heat release rate curve than the mattress fire, illustrated in Figure 11-1

- the first tenability limit to be exceeded was the visibility at 1.8 m which dropped below 10 m after 302 seconds and 262 seconds for Scenarios Three and Four respectively. Although this limit is credible in general building terms, it is not considered as critical as the toxicity and radiation limits in this case where the building form is very simple and disorientation less likely. The next limits to be exceeded were the FED radiation after 700 seconds and temperature after 701 seconds for Scenario Three, and temperature after 730 seconds and FED radiation after 778 seconds in Scenario Four.

- in general the Scenario Four room with tukutuku panel-lined walls achieved marginally increased times to untenable conditions over those in the Scenario Three room lined with totara. The one exception was the visibility limit in Scenario Four which was exceeded 40 seconds before that in Scenario Three.

- the development of the pyrolysis front is illustrated in Figure 11-6. The upward pyrolysis front (vertical spread consisting of spread up the wall and along the ceiling) reached the ceiling in Scenario Four 10 seconds before that in Scenario Three. After 600 seconds the ISO burner ramps up from 100 kW to 300 kW and while the fire in Scenario Three spreads across the ceiling quicker than that in Scenario Four, it is at most 40 seconds ahead. The most dramatic difference is in the lateral pyrolysis front (fire spread horizontally across the walls away from the fire source) with that in Scenario Four considerably quicker than that in Scenario Three. After 1200 seconds, the Scenario Three fire had spread laterally approximately 3 m to each side of the ISO burner while in Scenario Four it had spread 28 m, representing lateral fire spread fully across all wall surfaces (7 m across the back wall and 21 m along the side wall).

- the totara wall lining results in a worse fire safety scenario with consistently earlier times to both flashover and the tenability limits.

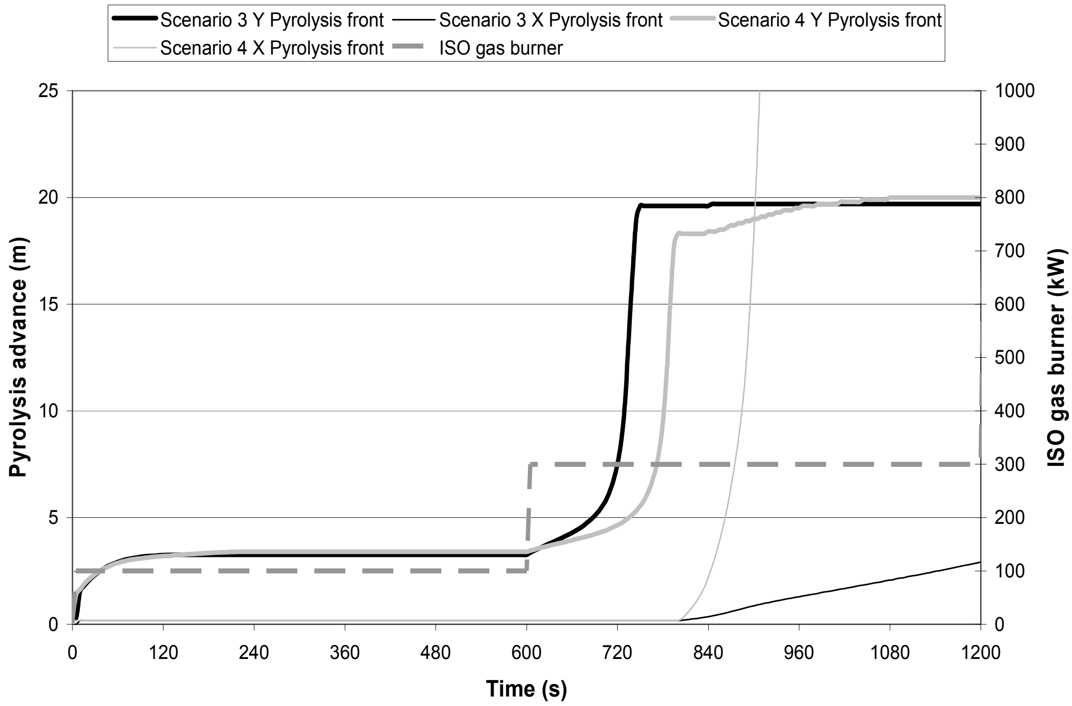

Figure 11-6: Pyrolysis front development in the X and Y direction for Scenarios Three and Four

11.5.2 Comparison of Scenarios Five, Six and Seven

Scenarios Five and Six investigate flame spread on the traditional totara and tukutuku wall linings respectively, and their influence on tenability in a realistic wharenui with a single means of escape and a realistic mattress ignition source. Scenario Seven is the same as Scenario Five but with two doors, each of double width to comply with NZBC Acceptable Solutions. Modelling found that:

- the tenability limits were reached considerably earlier than in Scenarios Three and Four where the ISO burner was the initial fire source (refer section 11.5.1). The mattress produces a considerably faster developing fire, reaching its peak heat-release rate after approximately 150 seconds (heat release rate curves for the ISO and mattress fires are illustrated in Figure 11-1).

- the first tenability limit to be exceeded in all three scenarios was the visibility at the observation point of 1.8 m above the floor.

- there was very little difference in the times to untenable conditions between all three scenarios. At most it was 10 seconds and for many there was no difference. This disguises significant differences between Scenarios Five and Six and Scenario Seven that are due to the increased ventilation area provided by the two double width doors in Scenario Seven. The differences are disguised because the upper layer in all three Scenarios descended below the observation point of 1.8m above the floor at approximately the same time. Figure 11-7 illustrates the difference in the layer heights between Scenarios Five and Seven. This translates to improved lower layer conditions when considering the O_2, CO_2 and CO concentrations, illustrated in Figure 11-8 and Figure 11-9. The conditions in the lower layer of Scenario Seven are significantly improved with O_2 not descending below 15%, the CO_2 peaks at 0.95% and CO at 3220 ppm. In Scenario Five the O_2 level descends to approximately 2%, while the CO_2 peaks at 1.46% and the CO at 5270 ppm. Although individually some of these conditions are survivable, the FED narcotic considers the overall cumulative effect of all three gases.

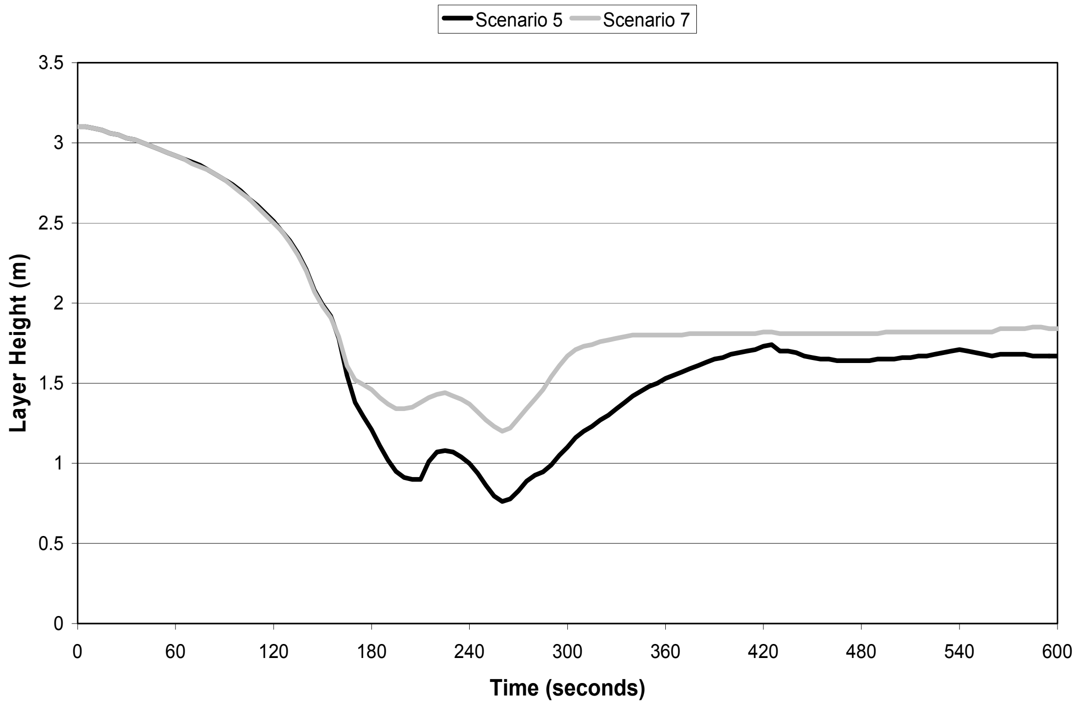

Figure 11-7: Height of interface between the upper and lower layers

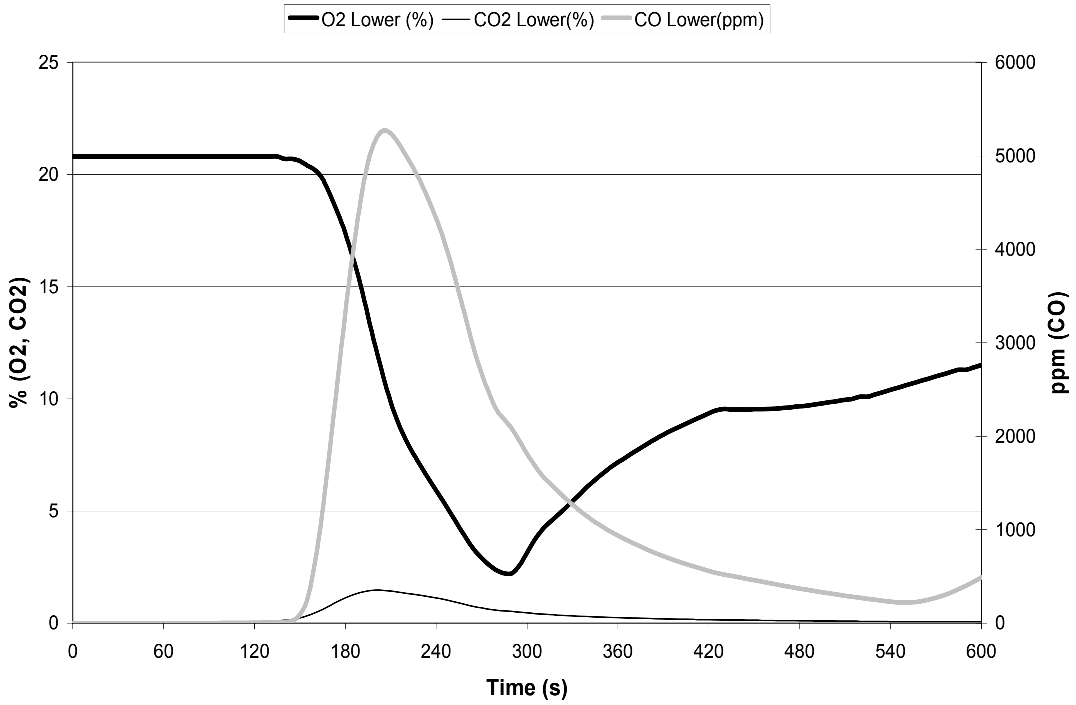

Figure 11-8: Scenario 5 O_2, CO_2 and CO levels in the lower layer

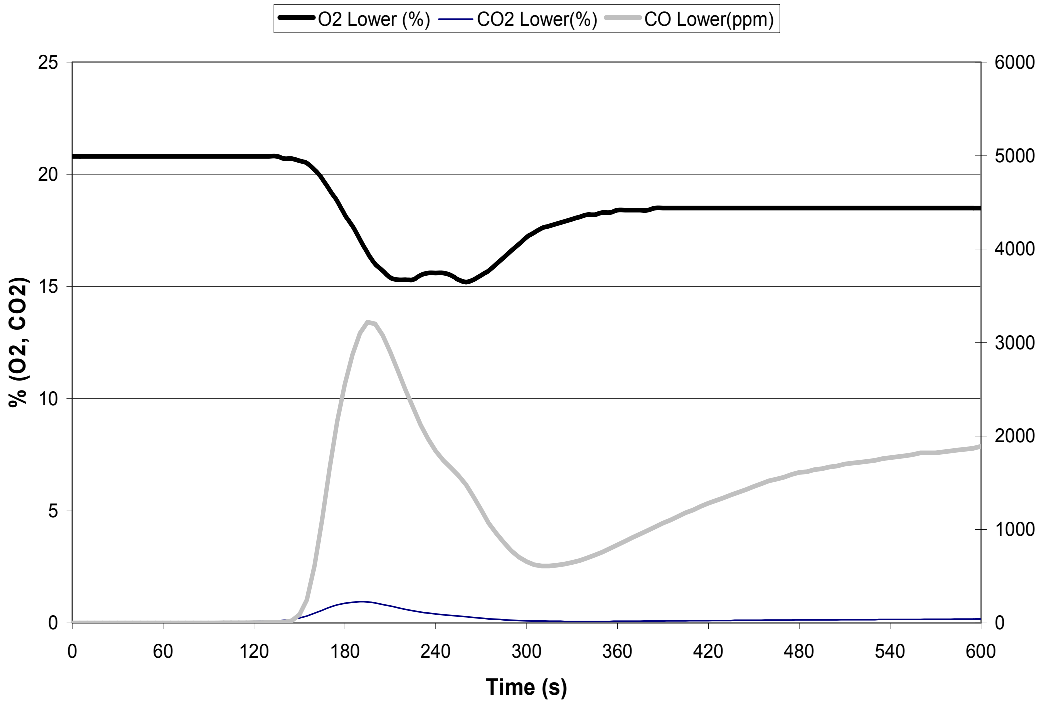

Figure 11-9: Scenario Seven O_2, CO_2 and CO levels in the lower layer

- the development of the pyrolysis front is illustrated in Figure 11-10. It is significant to note that the vertical fire spread (Y pyrolysis front) is virtually identical for all three scenarios. As in the comparison between Scenarios Three and Four, there is a dramatic difference in the lateral flame spread between the totara and the tukutuku panel linings. The lateral spread in Scenario Six (tukutuku) accelerates rapidly from 175 seconds after ignition spreading across all of the wall surfaces by 235 seconds. In contrast, the lateral flame spread across the totara lined walls in Scenarios Five and Seven is considerably slower. In Scenarios Five and Seven the lateral spread begins after approximately 210 seconds and after 600 seconds eventually reaches 6.8 m in Scenario Five and 3.6 m in Scenario Seven. It is important to note that while the totara-lined Scenarios performed significantly better than that lined with tukutuku panel, in all three the fire continued to spread long after the mattress fire source had decayed.

- this difference between Scenario Five and Seven is attributed to the additional ventilation provided in Scenario Seven effectively reducing the temperatures within the wharenui (refer Figure 11-11). The upper layer temperatures only differ in the decay phase, while in the lower layer the peaks are an average of 50 ^{o}C lower.

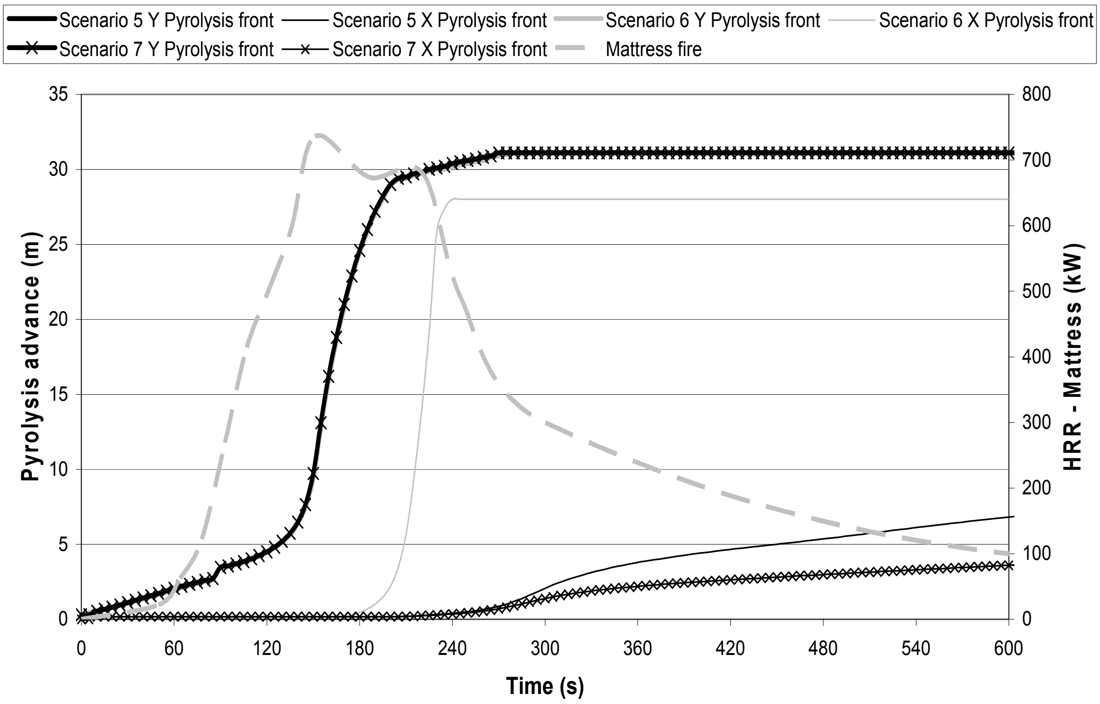

Figure 11-10: Pyrolysis front development in the X and Y direction for Scenarios Five, Six and Seven

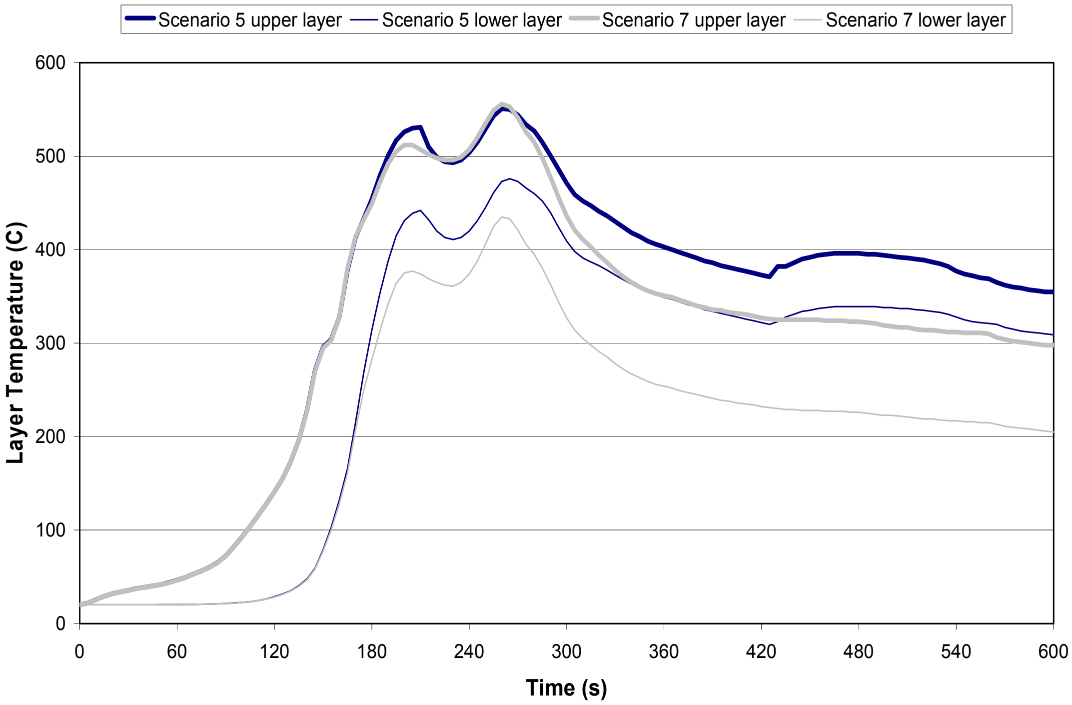

Figure 11-11: Upper and lower layer temperatures in Scenarios Five and Seven

11.5.3 Scenario Eight

Scenario Eight represents a conventional building that complies fully with the NZBC Acceptable Solutions. It has the same proportions and purpose group as a wharenui, but has internal linings that comply with the requirements in terms of flame spread for all other buildings and two standard size exits.

- in Scenario Eight, the first tenability limit to be reached was visibility after 125 seconds. As discussed earlier, it is not considered to be the most critical of the tenability limits given the simple building form. Also, in this scenario there are two exits available which for most occupants would provide line-of-sight distances within the 10m used in the visibility tenability determination.

- the next and critical tenability limit reached was the FED narcotic, exceeded after 205 seconds. This is 70 seconds greater than for any other scenario where the mattress was the fire source (Scenarios Five, Six and Seven). The FED narcotic is the cumulative dose calculation of the combined effects of reduced O_2, and increased CO_2 and CO gases. An interesting observation in Scenario Eight is the individual gas concentrations within the lower level (the layer height was maintained above 2m until 1100 seconds). The concentration levels illustrated in Figure 11-12 are all significantly lower than those recorded in Scenarios Five, Six and Seven.

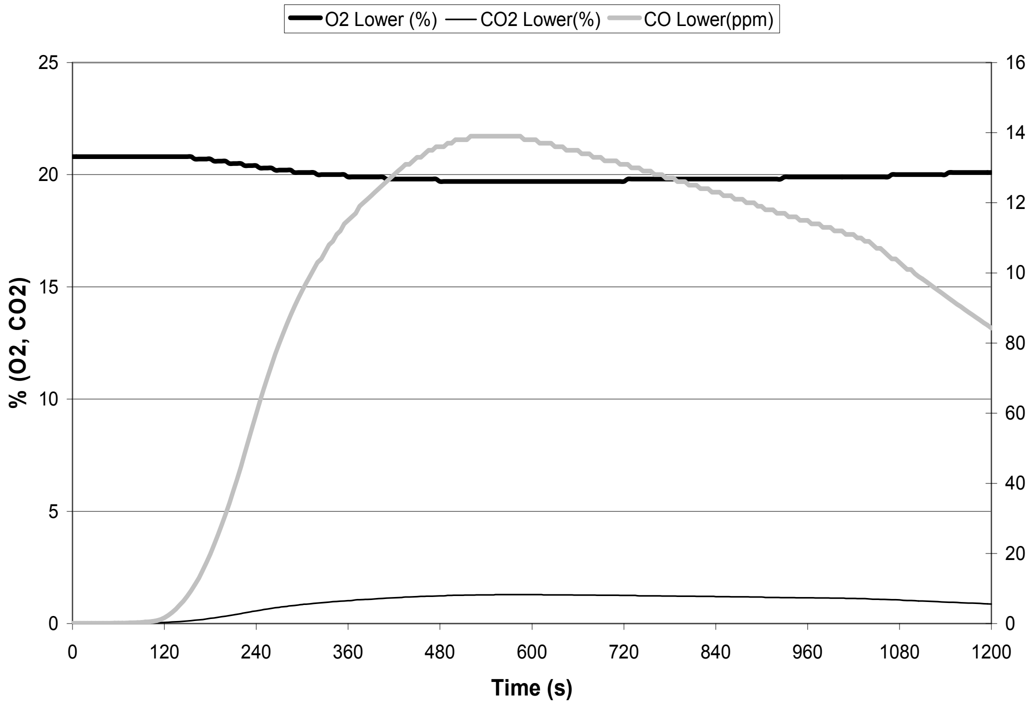

Figure 11-12: Scenario Eight O_2, CO_2 and CO levels in the lower layer

- a significant feature of Scenario Eight is that the fire did not flash over and none of the other tenability limits were reached. The upper and lower layer temperatures were considerably lower than those recorded in Scenarios Five, Six and Seven. These temperatures, together with the height of the layer interface, are illustrated in Figure 11-13.

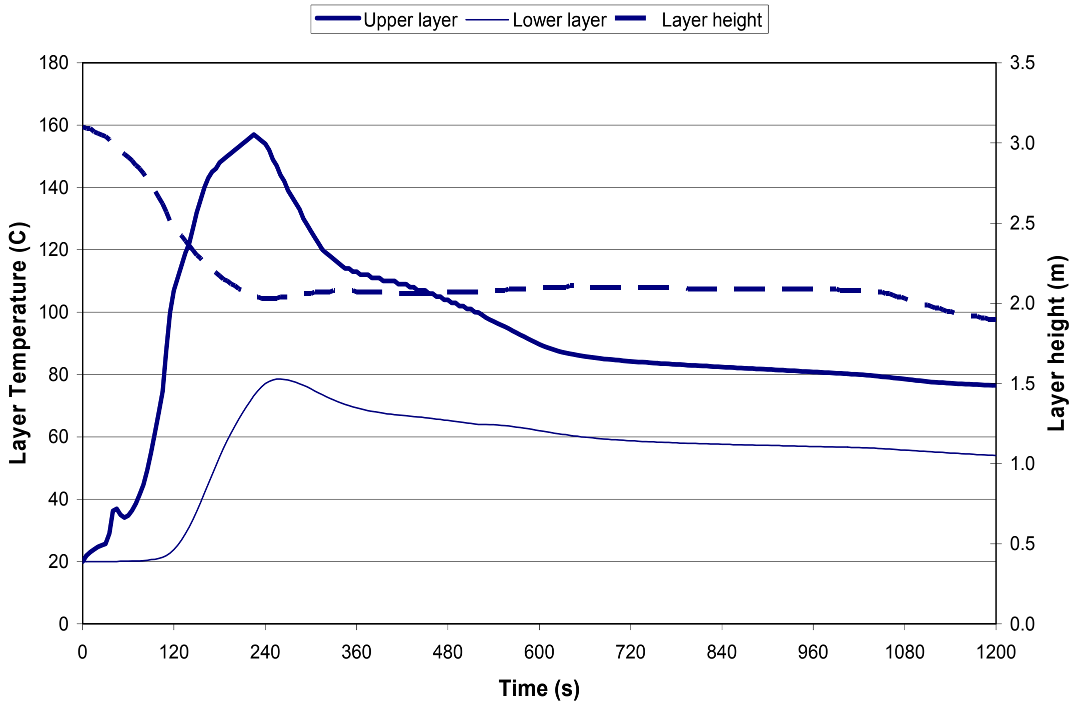

Figure 11-13: Scenario Eight upper and lower layer temperatures and height of the interface between the upper and lower layers

- the development of the pyrolysis front is illustrated in Figure 11-14. The significant feature in this graph is that it exhibits minimal travel of the pyrolysis fronts. The vertical fire spread (Y pyrolysis front) does not exceed 4.4m, and no spread in the lateral X direction. The 4.4m in the Y direction represents the pyrolysis front spreading up the wall reaching ceiling at 3.1m and travelling across the ceiling a distance of 1.3m. No lateral spread indicates there was insufficient fire development for this to occur.

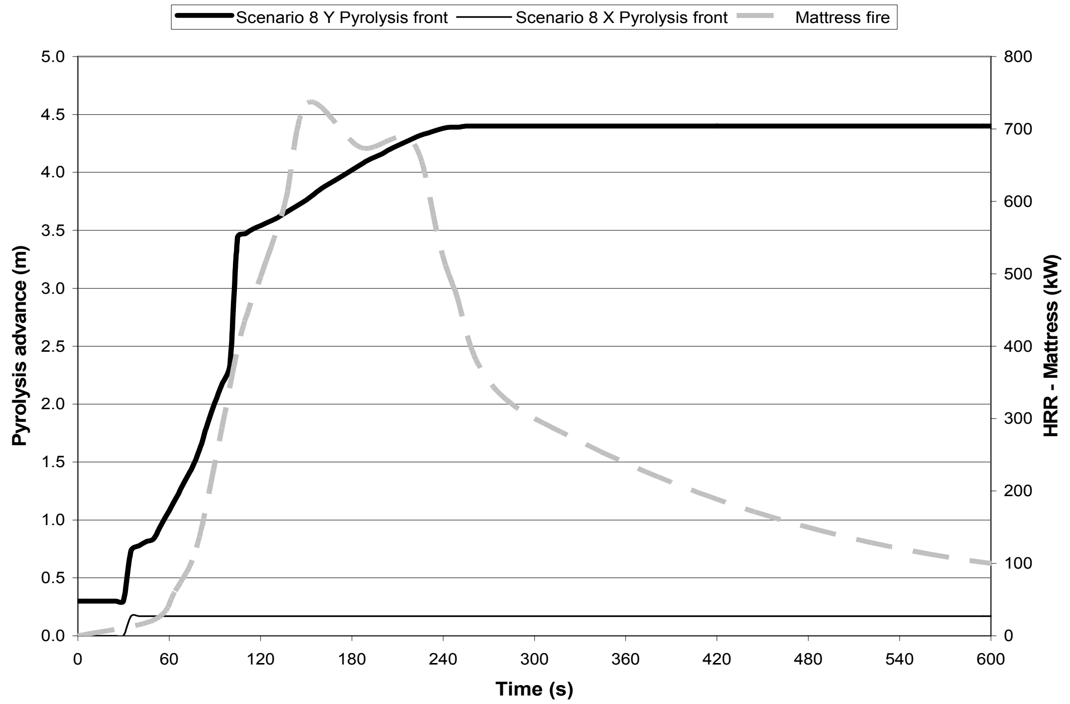

Figure 11-14: X and Y direction pyrolysis front development for Scenario Eight

11.6 Burn-through

In any fire there is potential for it to burn a hole through the bounding surfaces of the room of fire origin. Where this occurs it can alter the ventilation characteristics and consequently the development of the fire. It is important to note that burn-through was not able to be evaluated in the full-scale room test due to the outer concrete shell of the test room, and limitations in the computer model prevented burn-through being considered in the above modelling.

11.7 Evacuation analysis

Evacuation analysis for the sample wharenui is required for comparing alternative exit provisions with the time to untenable conditions. The analysis determines the required safe egress time (RSET), and subtracting this from the available safe egress time (ASET) determines the safety margin. The RSET is the minimum time it would take the occupants to evacuate, and the ASET is the time up to the onset of untenable conditions.

In this analysis three alternative exit provisions are evaluated.

1. A single door common to many existing wharenui.
2. Two exit doors, also common where the wharenui is linked to other buildings on the marae. Two doors are the minimum NZBC requirement for any other building providing SA purpose group accommodation.
3. Two double width exit doors, in full compliance with the NZBC requirements for wharenui lined with traditional materials.

The NZBC requires the wharenui to be classified as SA purpose group and in the absence of a sprinkler system limits the number of beds to 40, i.e. 40 persons. If a complying sprinkler system is installed, the occupancy limit is increased to 160 beds. The building is also able to accommodate between 150 and 200 people for meetings based on occupant densities of between 1.0 and 1.3 persons/m^2.

The evacuation times calculated here are the sum of three elements: the time taken for the alarm to be raised or activated, the occupant pre-movement time, and the time for passage.

The time for activation of the alarm of 20 seconds is based on the performance of a smoke detector. The design of the building is very open, allowing an efficient path for smoke to reach a detector and/or for the occupants to observe a fire start. Humans as a detector typically have a faster response time than electronic smoke detectors when awake and should achieve a reduced detection time.

The pre-movement time is the time taken for the occupants to respond, on hearing the alarm, and decide to evacuate. Two pre-movement times have been used: 15 seconds for awake occupants, and 30 seconds for occupants when the building is used for sleeping accommodation. These times are considered reasonable on the basis that all occupants are in the room of fire origin, assisted by the very open nature of the building, together with strong social group bonds that would lead to efficient assistance to prepare for evacuation in the event of a fire.

The time for passage evaluates the time taken for a particular number of occupants to pass through a narrow point, in this case the exit door. The method used to determine the ‘Time for passage’ is taken from the SFPE Handbook Section 3/Chapter 14 Emergency Movement, H. E. Nelson and H. A. MacLennan.

The time for passage (T_p) is measured in seconds and calculated using equation (1).

$$T_p = P/(1 - aD)kDW_e \text{ (s)} \tag{1}$$

Where	P	is the number of persons	
	a	constant	= 0.266
	D	density of persons/m^2	
	k	constant for aisles and doorways	= 1.4
	W_e	effective width of the exit door (m)	

It is important to note that all of the evacuation analysis was carried out on the basis that fire notification was achieved using automated smoke detection equipment.

Analysis of the evacuation is presented in **Error! Reference source not found.**. The ASET time of 135s is the earliest time at which untenable conditions are reached in all of the wharenui fires using the realistic mattress fire source. This is common with Scenarios Five and Seven with untenable conditions being reached in Scenario Six only five seconds later.

Table 11: Evacuation analysis summary

Number of occupants	ASET* (s)	Single standard width exit door e.g.: Scenarios Five and Six		Two standard width exit doors**		Two double width exit doors e.g.: Scenario Seven	
		RSET (s)	**Safety margin** (ASET-RSET) **(s)**	**RSET (s)**	**Safety margin** (ASET-RSET) **(s)**	**RSET (s)**	**Safety margin** (ASET-RSET) **(s)**
40 sleeping	135	185	- 50	118	17	84	51
150 awake		207	- 72	121	14	78	57
200 awake		233	- 98	134	1	85	50

- uses the tenability limits from Scenarios Five, Six and Seven
  ** Analysis of a wharenui of the same construction as Scenarios Five and Seven, but with two standard width exit doors (i.e. two doors at 850 mm each).

The safety margin provided by the fully compliant building in Scenario Eight is that for 'two standard width exit doors' plus 70 seconds (the difference between the Scenario Eight ASET of 205 seconds and Scenario Seven ASET of 135 seconds).

11.7.1 Evacuation analysis findings

The evacuation analysis of the building modelled here indicates that:

- a single exit door may not provide adequate egress from a wharenui in the event of a fast developing and uncontrolled fire
- increasing the number of exits to two may provide just enough exit capacity to evacuate the occupants, albeit without any margin for safety
- two double-width exits (in accordance with the NZBC Acceptable Solutions) offers an improvement over two standard-width exit doors
- the C/AS1 alternative for wharenui gives a lower level of safety than achieved by the benchmark (Scenario Eight) with compliant linings (refer **Error! Reference source not found.**). The Scenario Eight safety margins are calculated using the FED narcotic tenability time of 205 seconds.

Table 12: Predicted wharenui evacuation safety margins compared with NZBC

Number of occupants	Wharenui	NZBC benchmark	Reduction in the safety margin (%)
	Scenario Seven safety margin (s)	**Scenario Eight safety margin (s)**	
40 sleeping	51	87	41
150 awake	57	84	32

200 awake	50	71	29

Although it is reasonable to expect the high degree of affiliation between the occupants to provide assistance in the event of an evacuation, this cannot be relied upon or used in the justification for less than adequate exit provisions.

12. Building control implications

One of the objectives of this study was to investigate the ‘special case’ provisions given in C/AS1 for wharenui where interior surface finishes do not meet AS1530 Part 3 requirements, as discussed in Section 9.1 of this report. The ‘special case’ provisions required exit widths be doubled and open path lengths be halved.

The results of the experiments and modelling discussed in previous chapters lead to the conclusion that the ‘special case’ provisions do not fully compensate for the more flammable characteristics of the surface linings used and, overall, the level of life safety provided is lower compared to an alternative compliant building.

Although some concessions and relaxation of interior surface finishes can be justified given improved access to an exit, it is suggested that it is not appropriate to allow ceilings to be constructed of highly flammable materials in spaces where significant numbers of people congregate and sleep.

Figure 12-1 shows a possible approach to how C/AS1 might deal with the issue of surface finishes in wharenui and under what circumstances ‘sprinklers’ ought to be required if ‘untreated/unmodified’ materials are to be specified for the surface linings.

The suggested approach makes use of an alternative classification scheme for surface linings recently introduced to the Building Code of Australia in Amendment 13. The methodology was discussed in Section 9.3 of this report.

In brief, lining materials are classified into one of four groups (1-best to 4-worst) depending on their performance in AS/NZS 3837 or ISO 9705 fire test methods. The classification groups reflect the expected ‘time-to-flashover’ in the ISO 9705 room with:

Group 1 (G1) no flashover during the 20 minute exposure (typical of gypsum plasterboard).

Group 2 (G2) flashover occurs between 10 - 20 minutes exposure (typical of some FR-treated timber).

Group 3 (G3) flashover occurs between 2 - 10 minutes exposure (typical of untreated timber products).

Group 4 (G4) flashover occurs before 2 minutes exposure (typical of some foamed plastics, and including the toetoe and tukutuku construction studied in this project).

The grouping considered to best fit the existing ‘SFI not > 2’ C3/AS1 category is Group 2 (G2).

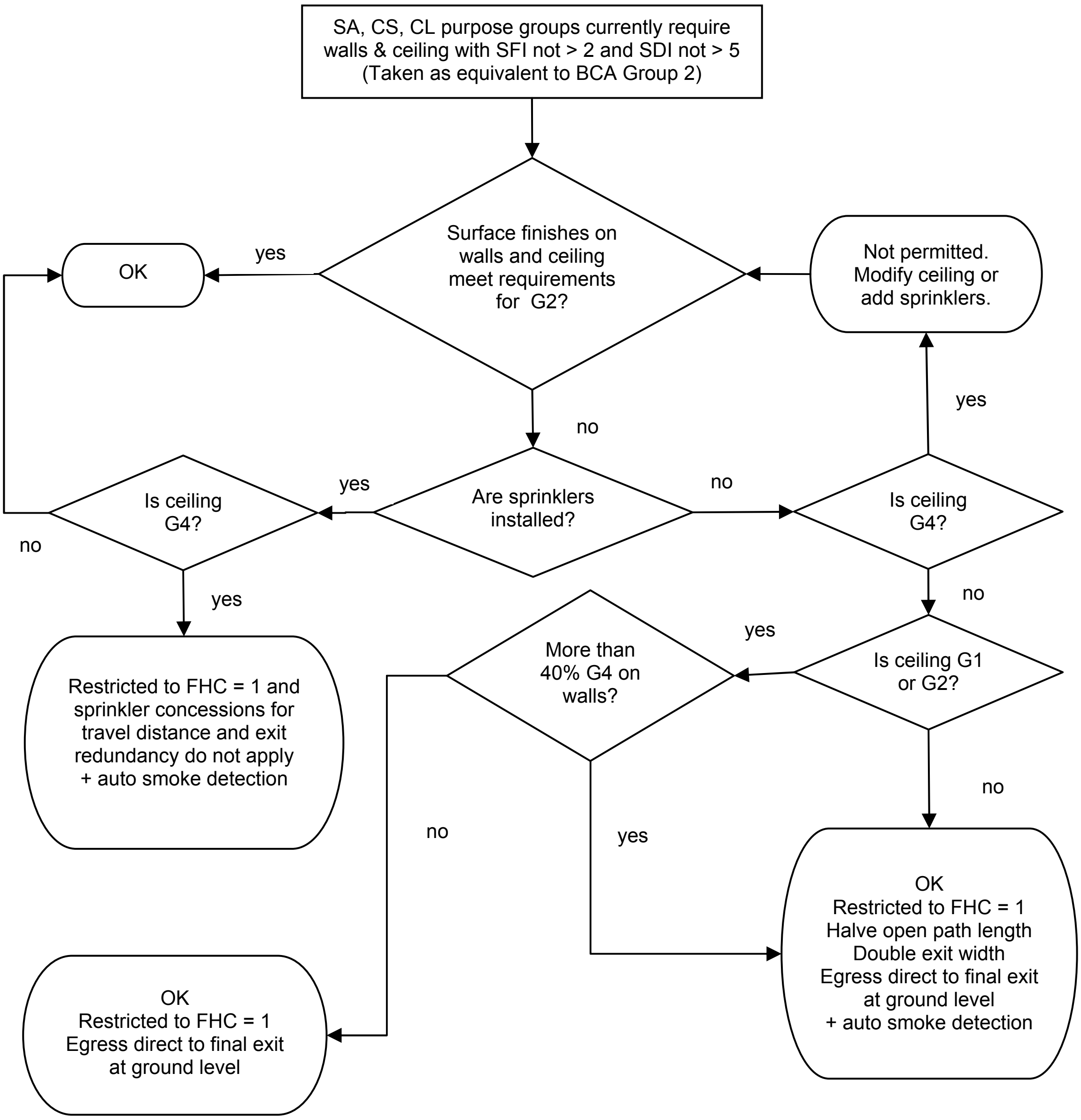

Figure 12-1: Flow chart of possible alternative approach to control of surface finishes applying to new construction of wharenui or similar buildings

13. Summary

The highly decorative marae wharenui constructed from traditional materials are not only important within the local Māori community, but also form a significant part of New Zealand's cultural heritage.

The full-scale test demonstrated that traditional Māori building construction is highly susceptible to fire and there is a very real potential that in the event of a fire it could threaten the safety of the occupants. The fire development was rapid resulting in the total loss of the tukutuku panels and toetoe in the ceiling and causing considerable damage to the larger timber members that would typically be intricately carved. This damage occurred within five minutes of ignition of the fire. It is therefore unrealistic to rely on Fire Service intervention to prevent or minimise this damage. The Fire Service states its response time to attend fires in urban areas is within eight minutes and in rural and remote locations it would be considerably longer.

The series of small-scale tests successfully characterised the individual materials and/or components used in the construction of traditional Māori buildings, providing a greater understanding of their performance in fire.

The BRANZfire computer program was demonstrated to successfully model the full-scale fire test based on the fire performance data collected from the small-scale test series.

The BRANZfire computer program was used to predict the fire spread and tenability conditions within a realistic scale wharenui, constructed from traditional materials.

The evacuation modelling carried out using the BRANZfire tenability predictions indicates that the alternative NZBC Acceptable Solution for wharenui result in a reduced level of life safety when benchmarked against an equivalent building with complying wall and ceiling linings.

A proposal for an alternative approach has been developed for the control of interior surface finishes in wharenui or similar buildings.

14. Recommendations

14.1 Life safety

The NZBC applies to any new construction, such as a completely new building or renovations and additions to be carried out on existing structures. It is not to be applied retrospectively unless a building is deemed unsafe or unsanitary, in which case it will address the provisions for evacuation and for access by persons with disabilities. The findings of this study identify that multiple exits from the wharenui are essential for the efficient evacuation of large numbers of people. It is therefore recommended that where existing wharenui have only a single exit that these are augmented with a second exit door located towards the opposite end. It is reasonable for the second door to be incorporated into the fabric of the building, such as the one at Otaki’s Ruakawa, but it must be clearly identified as an exit with appropriate signage.

All exits should be clearly identified with appropriate signage.

Case-specific fire safety action plans should be developed for all wharenui. An escape plan should be developed and exercised regularly, together with education on fire safety. All occupants should be made aware of the escape plan, their part in it, and the limits of expectations in regard to undertaking any fire-fighting activities.

Introducing fire safety management practices can greatly contribute towards reducing fire risk to life. It is recommended that no-smoking policies are implemented together with a ban on all naked flame sources, such as candles. Good housekeeping is also important, for example reducing the fuel load to the absolute minimum by storing mattresses when not in use in another building fire-separated from the wharenui.

Automatic fire alarms, such as smoke detection, should be installed in all areas that may be used as sleeping accommodation. The preferred system would be hard wired and linked to monitor all ancillary buildings.

14.2 Property preservation

Property preservation is left to the discretion of the building owner to include any measures to limit property damage from the effects of a fire, although incentives may be offered, for example, by insurance companies.

The mattress fire modelled in this report represents a real possibility initiating very fast fire growth. In the initial phase of a fire, the preservation of the building is up to the fire-fighting skills of those present and the equipment available to them, and/or the fire protection design features incorporated into the building. The Fire Service aim to attend urban fires within eight minutes from first notification of a fire. In more remote locations this time, as illustrated, can be considerably extended.

It is possible to incorporate many fire safety features into these buildings with minimal impact on the structure. Some options are:

- sprinkler system. A sprinkler system would provide the greatest level of property protection. A fully compliant system would be monitored, automatically calling out the fire service when the sprinkler system is activated. A sprinkler system would offer 24-hour protection to the building irrespective of whether it was occupied at the time. It is a high cost option requiring specialised equipment and a dedicated water supply. In some of the more remote rural locations, the availability of an adequate water supply may limit the use of a sprinkler system.

- sprinkler mist system. This is a modification of the standard sprinkler system using a fine water mist in place of heavier water droplets. As a consequence, it requires a much lower volume of water. This, like the conventional sprinkler system is a high cost option, offering the same benefits with the additional features of using less water and potentially causing less water damage.

- fire retardant treatment of the wall and ceiling lining materials. Fire retardant compounds are available that can increase the resistance of treated materials to ignite. These have the effect of delaying the time to ignition, but do not reduce the ability of the treated item to burn. In the event of a fire the retardant treatment may limit the rate of fire development and therefore the extent of the damage. Additional investigation work is required to assess the effectiveness of this option. Some of the questions to be answered relate to the required application rates, the durability of the application, its suitability and compatibility with the foundation materials, the appearance of the treatment, and any maintenance of the application.

- an alternative to fire retardants is the application of an intumescent paint coating. On exposure to fire, the intumescent paint expands to produce an insulating layer and thereby provides some protection to the substrate. The paint requires a certain temperature to intumesce (activate) and in reaching this temperature it may lead to damage of the substrate before the paint can perform its protective role. Like the fire retardants, there are many questions to be answered regarding the effectiveness and durability, acceptability of appearance, and maintenance, such as over-painting. Intumescent paints are most likely to be adequate only for protecting the major carvings, less so for the protection of woven panels and toetoe.

- monitored smoke detection alarm system. Smoke detection is recommended primarily to provide the earliest warning of a fire for the safety of occupants. A monitored system would be able to call out the fire service in the event of a fire when the building was empty.

- first aid fire-fighting equipment. The installation of first aid fire-fighting equipment should be considered, such as portable extinguishers and fire hose reels. There are many incidences where this equipment has been successfully applied to control or extinguish minor fires. However, it is important to stress that these should only be used while conditions remain safe to do so. Guidance on their use and the expectations placed on the operators should be defined in the fire safety evacuation scheme.

- passive fire protection. Adding fire stopping into the cavities behind the wall and ceiling linings would reduce the rate at which a fire can spread. In the full-scale test it was observed that fire spread through these cavities behind the linings.

An action plan for fire fighting should be developed with the local fire service - this is particularly important for isolated sites. It ensures familiarity with the building and site, identifies the availability of fire-fighting water supplies, and may include the preparation of a plan establishing the relative priorities for fire-fighting activities.

Regular maintenance around the building is recommended. The removal of stored or accumulated items that may provide an added fuel supply, such as chairs or mattresses inside, and the clearance of overgrown vegetation around the building outside, will reduce the likelihood of a large fire. It is also recommended that features such as the state of electrical wiring should be inspected on a regular basis.

Arson should also be considered in any fire safety plan, although it is very difficult to prevent someone intent on setting a fire. The best protection lies in having maintained and functioning fire suppression and or detection systems, preferably monitored to raise the alarm when the building is empty, and a limited availability of additional fuel sources, such as furniture and accumulated rubbish.

14.3 Preservation of the cultural heritage

It is important to protect the heritage classification of the wharenui, and modifications necessary to incorporate the fire safety features should be carried out as sympathetically as possible.

A framework for the implementation of practical fire safety features should be developed for retrospective installation, and for incorporation into any new or renovation work carried out on culturally significant buildings such as wharenui.

The international practice of documenting the historical significance of heritage buildings is recommended with regard to New Zealand’s traditional wharenui buildings.

14.4 Building control

The findings of this study indicate that the special case provisions included in the NZBC Acceptable Solutions for wharenui have resulted in a reduction in the level of life safety when compared to an alternative compliant building. It is recommended that the Acceptable Solutions are modified to address this. A possible approach has been included in this report.

It is strongly recommended that the installation of smoke alarms should be made mandatory, and where possible inter-connected with the ancillary buildings. This is particularly important in buildings providing sleeping accommodation, such as wharenui. At present, even in new wharenui construction, smoke detection is not required by the NZBC Acceptable Solutions where the exit doors open directly to a safe place or an external safe path. The findings of this study suggest that this is not adequate and smoke detection should be the minimum requirement.

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16. Glossary

Hapu	sub-tribe
Heke	rafters
Iwi	tribe
Marae	meeting area of a village and its buildings
Poupou	carved timber wall columns (in wharenui)
Tahuhu	ridge beam
Tamariki	children
Tangata Whenua	people of the land
Te Kohanga Reo	total immersion language programme for children from birth to six years of age
Te Reo	the Māori language
Tukutuku	woven wall panels
Whaihanga	make, build, construct
Wharekai	dining hall
Wharenui	meeting house