Determination 2006/52

Single means of escape from a high-rise apartment building at 18 Turner Street and 17-19 Waverley Street, Auckland City

1 The dispute to be determined

1.1 This is a Determination of a dispute under Part 3 Subpart 1 of the Building Act 2004 ("the Act") made under authorisation by me, John Gardiner, Determinations Manager, Department of Building and Housing, for and on behalf of the Chief Executive of that Department.

1.2 The applicant is Tasman Properties Limited acting through the project manager for the development ("the applicant"). The other parties are the Auckland City Council ("the territorial authority") and the New Zealand Fire Service Commission ("the Fire Service"), which has the right or obligation to give written notice to the territorial authority in respect of these matters.

1.3 I take the view that the matter for Determination is whether a new apartment building with a single means of escape from fire complies with Clauses C2 and C3 of the Building Code (the First Schedule to the Building Regulations 1992) as required by Sections 177 and 188 of the Act.

1.4 The Department commissioned a firm of specialist consulting engineers ("the experts") to assist me in establishing Building Code compliance. In making my decision, I have considered the submissions of the parties, the fire report prepared by the experts ("the experts' report"), and the other evidence in this matter. I have not considered any other aspects of the Act or the Building Code.

2 Procedure

2.1 The building

2.1.1 The proposal at 18 Turner Street and 17-19 Waverley Street, Auckland consists of two apartment towers. The Waverley tower is fourteen stories high above ground level and is constructed above three levels of basement carparking. The Turner tower is thirteen stories high above ground level and is constructed above two levels of basement carparking. The two towers are linked through both of the lower carparking levels. The ground floor level of the Turner tower includes a manager's office, a rubbish and locker area, and two apartments.

The Waverly tower has six apartments on the ground floor and seven apartments on each of the remaining floors. Levels 1B to 10B of the Turner tower each have five apartments, and level 11B has seven apartments, six of which have upper-floor mezzanines. All the apartments have either one or two bedrooms.

Floor plans showing the two towers and their relationship are included as Appendix A.

2.1.2 All of the apartments open onto internal horizontal corridors, which provide access to the stairway and lifts. The proposed building has a:

- F 60 fire cell rating of 60 minutes
- Type 7e system that has a sprinkler system with a Class B dual water supply and includes smoke detectors and manual call points throughout the buildings
- Type 8 "voice message" communication system for use by fire fighters
- Type 15 Fire Service lift control
- Type 16 emergency lighting system in the exit ways
- Type 18 fire hydrant system.

2.1.3 A typical floor plan for Waverly Tower is reproduced in Figure 1. Figure 2 shows a cross section through both towers[1].

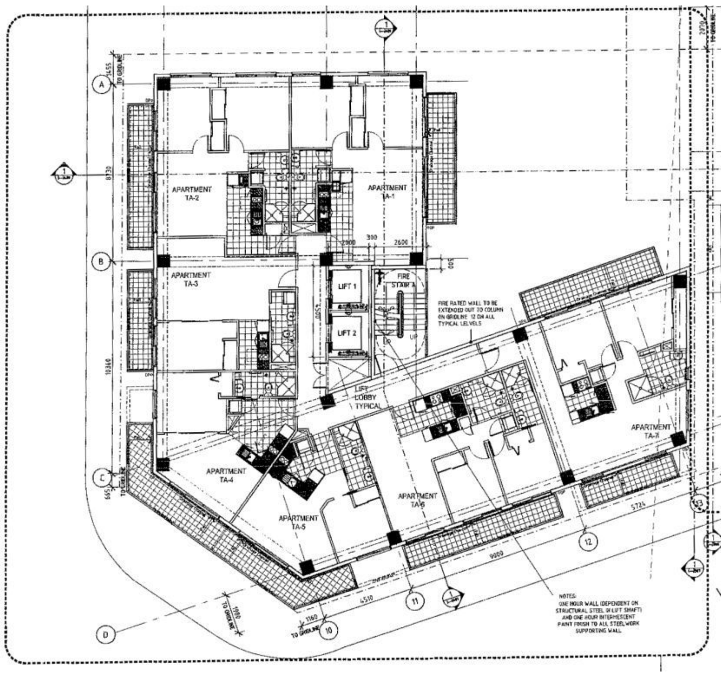

Figure 1: Typical plan of Waverly Tower

[1] *From the Architect's drawings No 106 dated May 04 and No 400 dated April 04*

Turner Tower **Waverly Tower**

Figure 2: Section through both towers

2.2 Sequence of events

2.2.1 The apartments are to be constructed following the issue of a building consent, which is contingent upon this Determination. Initial application for the building consent was made prior to January 2005. The application included copies of "Fire Engineering Design, Turner-Waverley Apartments" Volumes 1 and 2 ("the fire reports").

2.2.2 On 27 January 2005 the territorial authority wrote to the applicant advising that, as the proposed works included a single means of fire egress, which places the building's fire design outside the scope of NZBC-C/AS1, and "until a level of performance equivalent to that required by NZBC acceptable solutions is demonstrated, Council are not satisfied on reasonable grounds that the provisions of the building code would be met if the building were to properly completed in accordance with the plans and specifications submitted for consent".

2.2.3 A fire engineering consultant, Enlightened Solutions Ltd was engaged by the applicants to peer review the fire engineering design and the fire reports for the project. This firm wrote to the project manager on 4 February 2005 stating that the relevant provisions of the Building Code would be met if the fire engineering work was properly completed in accordance with the plans and specifications forming part of the application, together with the additional correspondence that occurred as part of the peer review.

2.2.4 The territorial authority sent a facsimile to the project manager on 1 March 2005, noting that the applicant was requesting the territorial authority to issue a building consent on the basis of the peer review. The territorial authority reiterated its position that either a second means of escape should be provided to both buildings or that a determination be sought from the Department. The territorial authority was of the opinion that in order to bench mark an alternative design against an Acceptable Solution, a risk analysis is required comparing one against the other.

2.2.5 The applicant applied for a determination on 16 September 2005. The Fire Service was provided with copies of the submission.

2.2.6 On the 5th October 2005, I engaged a form of specialised consulting fire engineers (the "experts") to assist me in assessing building code compliance.

2.2.6 The experts produced their report, which was completed 14 December 2005. Copies of the final experts' report were sent to the territorial authority, the applicant, and the Fire Service on 22 December 2005. The territorial authority acknowledged receipt of the report on 13 January 2006 and noted that it had no comment to make.

3 The submissions

3.1 On the evidence provided to the Department, the application appears to have been quite straightforward in that the territorial authority required both revised drawings and a fire safety report that showed the provision of a second escape route. Alternatively, a Determination from the Department in favour of a single means of escape from the building would be required.

3.2 Under the "matter of doubt or dispute", the applicant stated that the two buildings in question are over 25 metres in height and, apart from them having a single means of escape, the design complies with Acceptable Solution C/AS1. The applicant noted that the Act allows for alternative solutions and the fire consultants had designed such a solution that compensated for the lack of a second escape route. The compensating factors can be summarised as being:

- improved isolation from fire spread
- an improved alarm and evacuation system
- an improved automatic fire sprinkler system
- external naturally ventilated stairways.

The applicants contended that Determinations 2003/3 and 2005/109 related to buildings of a different architectural design and different fire engineering design components from the buildings in question. Accordingly, they did not relate to the latter. The applicant was of the opinion that the submitted fire reports complied with the Building Acts of 1991 and 2004 and the Building Regulation 1992. The fire engineering design was "acceptable and sufficient" and had been verified by a peer review.

3.3 As part of its submission, the applicant provided copies of:

- the fire reports
- correspondence with the territorial authority and Enlightened Solutions Ltd
- a producer statement from Enlightened Solutions Ltd.

3.4 Following a request from the experts, the applicant also supplied architectural drawings titled "Turner Waverly Apartments", dated for various months of 2004 and varying in revision status

3.5 Copies of the submissions and other evidence (apart from that listed in 3.3 above) were provided to each of the parties. The owner and the Fire Service made further submissions in response to the experts' report.

4 The relevant provisions of the Building Code

4.1 The dispute to be determined is whether the territorial authority's decision to refuse a building consent for the buildings because it was not satisfied that their single means of escape from fire complied with Clauses C2 and C3 of the Building Code (First Schedule, Building Regulations 1992) is correct.

4.2 The relevant clauses of the Building Code are:

Clause C2—MEANS OF ESCAPE

OBJECTIVE

C2.1 The objective of this provision is to:

(a) Safeguard people from injury or illness from a fire while escaping to a safe place, and

(b) Facilitate fire rescue operations.

Clause C3—SPREAD OF FIRE

OBJECTIVE

C3.1 The objective of this provision is to:

(a) Safeguard people from injury or illness when evacuating a building during fire.

(b) Provide protection to fire service personnel during fire fighting operations.

(c) Protect adjacent household units, other residential units, and other property from the effects of fire.

(d) Safeguard the environment from adverse effects of fire.

4.3 The relevant performance statements deriving from these objectives are incorporated in Clauses C2.3 and C3.3 of the Building Code. I note that the applicant is required to satisfy these latter performance requirements in order to comply with the Building Code.

4.2 Fire safety features necessary to comply with the Acceptable Solution

4.2.1 The relevant provisions of the Acceptable Solution C/AS1 amount to a means of compliance with the performance requirements of Clauses C2 and C3 of the Building Code.

4.2.2 In order to comply with the Acceptable Solution C/AS1, a sprinklered multi-unit residential dwelling (Purpose Group SR) having an escape height from fire of 41 m (12 storeys) and containing the same apartments and rooms as the proposed building would be required to have the following significant fire safety features:

- an automatic fire sprinkler system with smoke detectors and manual call points (allowing local notification of smoke detector activation in apartments)
- two separate means of escape stairways separated by fire rated construction
- a fire cell rating of no less than F45
- fire separations of the safe path to be 30/30/30 (reduced from 60/60/60 due to provision of sprinklers)
- lifts within a protected shaft
- exit doors from apartments required to open directly onto a horizontal safe path, a pressurised vertical safe path, or a final exit
- a horizontal protected path at each floor level (other than the top floor) preceding the vertical safe path. The protected path and vertical safe path are to be separated by fire doors.

4.2.3 There are no Acceptable Solution’s that have been approved under Section 22 of the Act or Section 49 of the Building Act 1991 that cover single means of escape for buildings of this configuration and size. I am, therefore of the opinion that the system proposed to be installed must now be considered to be an alternative solution.

4.3 Fire safety features proposed as an alternative solution

4.3.1 The proposed building therefore differs from one complying with C/AS1 in that:

(a) It has a single escape route instead of two as required for a sprinklered building with an escape height exceeding 25 m.

(b) The sprinkler system will have a dual ‘Class B’ water supply.

(c) The egress widths of the stairs are 1200mm.

(d) A voice communication system (Type 8 of C/AS1) is provided.

4.4 Alternative solutions and Acceptable Solutions

4.4.1 In comparing an alternative solution with an Acceptable Solution it is useful to bear in mind the objectives of the relevant Building Code clauses.

4.4.2 The applicant contends that the design is an alternative solution complying with the Building Code.

4.4.3 With regard to this contention, I note that the Authority said in Determination 2004/5:

> "5.2.2 As for the proposed alternative solutions, the Authority's task is to determine whether they comply with the performance-based Building Code. In doing so, the Authority may use the Acceptable Solution as a guideline or benchmark[2].
>
> 5.2.3 The Authority sees the Acceptable Solution C/AS1 as an example of the level of fire safety required by the Building Code. Any departure from the Acceptable Solution must achieve the same level of safety if it is to be accepted as an alternative solution complying with the Building Code.
>
> 5.2.4 As in several previous Determinations, the Authority makes the following general observations about Acceptable Solutions and alternative solutions:
>
> (a) Some Acceptable Solutions cover the worst case so that in less extreme cases they may be modified and the resulting alternative solution will still comply with the Building Code.
>
> (b) Usually, however, when there is non-compliance with one provision of an Acceptable Solution it will be necessary to add some other provision to compensate for that in order to comply with the Building Code."

4.4.4 In the light of comments made separately, I then stated:

> "I accept that the Authority's reference to "the worst case" is too broadly worded in an application of this type. A better formulation would be:
>
> (a) Some Acceptable Solutions cover the worst case of a building closely similar to the building concerned. If the building concerned presents a less extreme case, then some provisions of the Acceptable Solution may be waived or modified (because they are excessive for the building concerned) and the resulting alternative solution will still comply with the Building Code.
>
> (b) Usually, however, when there is non-compliance with one provision of an Acceptable Solution it will be necessary to add some other provision or provisions in order to comply with the Building Code."

"[2] *Auckland CC v NZ Fire Service* [1996] 1 NZLR 330."

5 The experts' report

5.1 The experts' report provides specific information on the single means of escape from fire in the building. The main features of the experts' report can be summarised under the following general headings:

- Introduction
- Description of the building
- Design philosophy
- Methodology
- Risk identification
- Risk analysis
- Risk evaluation
- Results
- Outcome.

5.2 Introduction

5.2.1 The experts used documents provided by the Department, including the fire reports prepared on behalf of the applicant, to evaluate the application. Those documents are listed in paragraph 3.3. They sought and received further information as outlined in paragraph 3.4.

5.3 Description of the buildings

5.3.1 The experts described the buildings in relation to their fire safety aspects and noted that the escape routes from both the Waverly tower and the Turner tower were unorthodox in their design. Taking into account this factor, the experts established that the escape height for Waverly tower was 41 metres and that for the Turner tower it was 38.4 metres. The experts described the features that the designers had introduced that were enhancements to the buildings and which were considered as being significant in the preparation the experts' report. These were:

- a sprinkler system with a Class B dual water supply, instead of a Class C single water supply
- the stair in each tower being open on one side and while these are not external stairs, there is a benefit. However, this benefit is less than that subjectively assumed in the fire reports
- the stair egress widths being 1200mm wide rather than 1000mm wide.

5.3.2 The experts also noted other enhancements that were not considered as being significant as regards the expert's report. These were the:

- voice communications system
- first aid fire fighting systems.

5.3.3 For the purposes of analysis and comparison, the experts analysed two buildings. One of these was the Waverly tower, for which the experts have taken what they describe as the "simplifying yet conservative" assumption, that it is a stand-alone building, and is referred to hereinafter as Building A. This assumption ignores the positive benefit of the secondary means of escape from level 1A of the Waverly tower to level 1B of the Turner tower. It is also assumes that if The Waverly tower with its single means of escape is code-compliant, then so will be the Turner tower. In the risk assessment, Building A is then compared with an "idealised" building, referred to as Building C. This building is of the same height, plan area, and occupant load as Building A, but as it has two stairways, it complies with C/AS1.

5.3.4 In terms of fire safety precautions the experts considered that the only enhancement that Building A has over Building C is that the fire cell rating is increased from 45 minutes to 60 minutes. Conversely, Building A is deficient when compared with Building B as it has only a single means of escape. The experts were of the opinion that fire report proposal offered few enhancements to compensate for the deletion of the second stair.

5.4 Protect in place evacuation strategy

5.4.1 The experts noted that the proposed evacuation procedure involves a "progressive" or "cascading" strategy. This strategy has its merits and was promoted by the New Zealand Fire Service (Davis 2004) from which the fire report has gained the "Apartment fire safety evacuation scheme". It is not clear whether the Fire Service intended this application to apply to single means of escape building.

Progressive or cascading evacuation is described in the IFEG (ABCB 2005) under the broader term of "protect in place" evacuation strategies:

> "A further more recent development is the 'protect in place' concept, particularly for residential buildings that are fully sprinklered. Occupants are encouraged to remain where they are rather than try to evacuate through potentially smoke-filled corridors or stairs".

The IFEG carries on to say, in terms of its own application:

> "While many of these newer occupant management and evacuation concepts are still developing, these guidelines are restricted to addressing the situation where evacuation of occupants to a place of safety is adopted as the approach in a fire emergency."

5.4.2 Notwithstanding the merits of protect in place evacuation strategies, it is as-yet a developing science and beyond the scope of contemporary design.

The question has also been raised as to whether this type of strategy complies with the building code. Referring to Determination 2005/134, in which I said:

"6.4.2 "Protect in place" strategy

6.4.2.1 As discussed above the "protect in place" concept is not one I believe was contemplated by the Acceptable Solution C/AS1, or I would suggest, by provisions C2 and C3 of the Building Code itself.

6.4.2.2 In my view, the objective of the “means of escape” provision within clause C2 of the Building Code is clearly to “safeguard people from injury or illness from a fire whilst escaping to a safe place”. Clause A2 of the Building Code defines a “safe place” as a place of safety in the vicinity of a building from which people may safely disperse after escaping from the effects of fire. It may be a place such as a street, open space, public space, or an adjacent building.

6.4.2.3 Consequently, if a “protect in place” concept was to be relied on in this building as a primary means of ensuring safety of building occupants then a modification of clause C2 would be required, solely on the grounds that the safeguards put in place to protect people from the effect of fire were not aimed at achieving exit to a safe place.”

Given the above, an “all out” evacuation strategy is assumed for the purposes of the risk analysis. This means that the calculation of required safe egress time does not include the time delay arising from occupants being held in their apartments. On one hand this makes the analysis conservative in that it assumes that maximum occupancy within the stairwell thereby raising the overall risk. Conversely, it is less conservative in that if a progressive evacuation strategy is adopted, untenable conditions may be created in the stair before the Fire Service calls for building evacuation.

5.5 The analysis

5.5.1 The experts considered two cases in their analysis, these being:

Case 1: The proposal as submitted in the applicants fire reports.

Case 2: The proposal as recommended in the experts’ report.

5.5.2 Referring to the manner in which a comparative analysis is carried out, I note that in Determination 2004/65 the Authority has said:

“6.1.1 The Authority takes the view that as a matter of law this Determination is binding only on the parties and only in respect of the building concerned.

6.1.2 Nevertheless, the Authority recognises that people considering other buildings will frequently use a Determination for guidance. The Authority therefore tends to set out its reasoning in more detail than may be strictly necessary for the particular case, in the hope that the reasoning, as distinct from the conclusions, will be of use as an example of the process of arriving at a decision in a different case involving comparable circumstances.

5.5.3 I take the same view in this case, but also note that these buildings and particularly their configuration and floor layout are not common. Any broader interpretation of the conclusions of this Determination must acknowledge that fact.

5.5.4 Figure 3 (below) shows a typical floor plan for Building C[3], (the corresponding building deemed to comply with C/AS1. Note additional stairwell lower right).

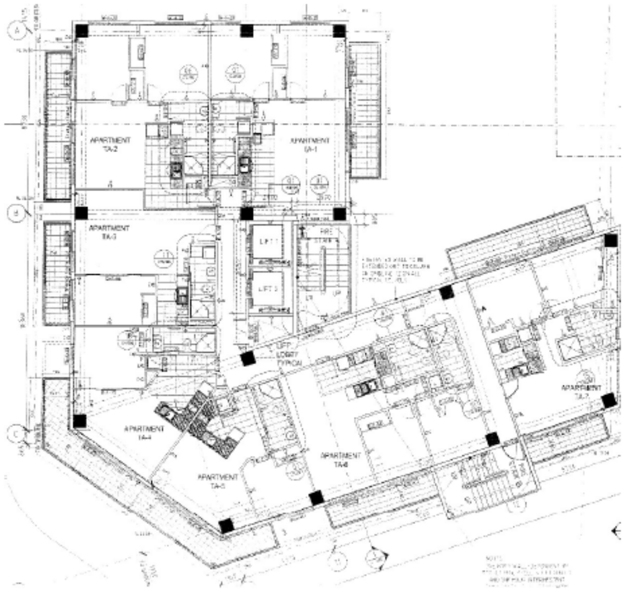

Figure 3: Typical floor plan for building C

5.6 Risk design philosophy

5.6.1 The IFEG guidelines suggest that any but the simplest of alternative solutions should be justified on a quantative basis. In the experts' view, the most suitable quantative methods of analysis to establish the impact of these various elements on levels of fire safety are probabilistic-comparative or probabilistic-absolute. Previously, most analyses were based on deterministic methodologies.

5.6.2 The experts then referred to Determination 2005/109, which established that a probabilistic-comparative approach is the more appropriate analysis method for cases such as this, without precluding the probabilistic-absolute approach. Determination 2005/109 had considered the fire safety compliance of an 18-storey multi-unit apartment building, with a smaller floor plate area, in terms of how its features compare with the corresponding (C/AS1) Acceptable Solution building.

5.6.3 Specifically at paragraph 6.2.4 of that Determination, I said:

"…I consider that the type of comparative risk analysis used in the assessment is an appropriate method for deciding whether an alternative solution is effectively equivalent to the corresponding Acceptable Solution in terms of fire safety. In particular, I accept the following comment from Expert I (a consultant engaged for that matter) as below:"

"In considering changes to the fire safety system in a building of the sort proposed, (deletion of a stairway, improvements to the sprinkler system, stairway pressurization, etc) it needs to be understood that each of these changes affects the level of fire safety in the building in different ways. Consequently the only way of comparing these changes is on a risk basis – how much (and in which direction) each of them changes the level of safety in the building."

[3] *From the Architect's drawing No 106 dated May 04 with the addition of the stairway*

5.6.4 I am aware that there are some in the fire engineering community who favour absolute approaches, whether deterministic or probabilistic. A deterministic-absolute approach is not appropriate in this case and the current construct of the Building Code is such that there is insufficient performance-based information for a probabilistic-absolute approach. By this, I mean there is no information as to the quantified tolerable or acceptable levels of risk to be used as measuring point of compliance. Until these are developed, a probabilistic-comparative approach with the acceptable solutions as the comparator remains the most appropriate means of analysing these issues.

5.6.5 In the current case the experts noted that the fire reports offered no quantitative analysis, either deterministic or probabilistic. Instead, the report included the qualitative statement:

"A single escape route is appropriate to this escape height due to the protection offered by the escape stair, i.e. Building is sprinkler protected, and the stairs are open to the outside allowing passive smoke ventilation. Therefore the stair would not become smoke logged in the event of fire"

According to the experts, this "subjective justification" did not establish reasonable grounds to establish code-compliance. In addition, the hazard analysis using computational fluid dynamic (CFD) analysis indicated that the "no smoke logging" assumption was not in fact valid.

5.7 Methodology

5.7.1 The experts stated that the assessment of the single means of escape for the apartments requires a risk-based approach. This involves the designer undertaking a risk assessment. Risk assessment is defined as the overall process of:

- risk identification
- risk analysis
- risk evaluation.

5.5.2 This process and structure is consistent with that defined in AS/NZS4360 (SAA 2004) "Risk Management". I describe these more fully in the following paragraphs.

5.8 Risk identification

5.8.1 The experts defined risk identification as "the process of determining what, where, when, why, and how something could happen". The risk identification in the context of their assessment is primarily concerned with the impact on life safety, taking into account the escape stairway contribution within the applicant's Building A, as compared to the corresponding compliant Building C.

5.8.2 The primary scenario that is evaluated by the experts is that arising from a fire in an apartment. The following paragraphs are structured around this scenario. It evaluates the risk to occupants of both the apartment of fire origin and occupants of apartments on the same floor level and above, should the fire spread. The experts' CFD analysis showed the "passive ventilation" from the Building A stair from a spreading apartment fire to be ineffective. Despite being open to the exterior on one face for most of its height, the stairwell becomes, and remains, untenable after a short period of smoke-filling. Based on this finding, the experts considered that an arson “attack” should be identified as a “secondary risk scenario”. Arson scenarios are not generally considered in fire designs as a credible fire scenario. The arson scenario sits outside of the current risk analysis and is considered as a parallel hazard check.

5.8.3 The CFD results showed that a slowly rising smoke layer and a hazard occurs when occupants meet asphyxiating or toxic conditions on entering what appears to be a tenable stair. The occupants therefore need to be able to re-enter the corridor at each level. Accordingly, the stairwell doors needed a locking system that would grant such access in fire alarm conditions. As the stair is open on one face, smoke detectors are not feasible. However, tamper-proof manually-operated call points would be a feasible alternative.

5.9 Risk analysis

5.9.1 Design philosophy

5.9.1.1 The design philosophy that is being proposed and tested in the risk analysis involves the two case scenario described in paragraph 5.5.1. The analysis shows that:

In the submitted Case 1 scenario, the small increase in sprinkler reliability enhancement for Building A does not compensate for the lack of a second stair.

In the recommended Case 2 scenario, the corridor pressurisation system added to Building A protects the stair from smoke spread and provides improved safety to the occupants on the same floor as the apartment of fire origin.

6 Event tree analysis

6.1 The experts developed an event tree for both Building A (termed “Event Tree “A” or “ET-A”) (where both Case 1 and Case 2 were considered), and for Building C (“ET-C”). A sequence of events, including their probability distributions, resulted in a number of outcome scenarios. The events are summarised in the following Table 1, which is reproduced from the experts’ report.

Table 1: Summary of Events

Event	Description of event (yes)
1	Ignition occurs (initiating frequency)
2	Fire origin is in an apartment
3	Fire growth is limited, i.e.; not a flaming fire that would cause detection in an operating detector and untenable conditions are not reached
4	The occupant is awake

5	There is manual suppression or the fire self-extinguishes and untenable conditions are not reached
6	The automatic suppression system (sprinkler system) is effective and untenable conditions are not reached
7	The automatic alarm is effective and warning is given
8	The first fire separation (barrier 1) between the apartment and corridor is effective
9	The corridor pressurisation system is effective (ineffective if not present)
10	Given that the first fire separation (barrier 1) has failed, the second fire separation (barrier 2) is effective between the corridor and Stair I
11	Given that the first fire separation (barrier 1) has failed, and conditional upon whether the second barrier (barrier 2) fails or not, the third fire separation (barrier 3) is effective between the corridor and Stair II. (ineffective if no stair II)

6.2 Probabilities

6.2.1 The event trees for each building are simplified, share the same layout, and are based on the same template. The experts noted that the probabilities varied between the event trees, particularly as regards the comparable sprinkler systems, the number of stairways, and the pressurisation system. The “ET-A” and “ET-C” event trees are constructed to test the points of difference between the two buildings. These points of difference (or compensation) are:

- that the Class B water supply system to the sprinkler system in Building A enhances that system when compared with the sprinkler system of Building C
- The lack of a second stair in Building A.
- the substitution of a corridor pressurisation system in Building A to compensate for the lack of a second stairway within Building C.

6.2.2 The report noted that events 1 to 5 are common to both event trees, and these with the exception of event 4, were given values of unity. The report gave an in-depth explanation of the probability data used in the analysis for events 4, 6, and 8 to 11 as described in Table 1 “Summary of Events”. For each event the probability was identified in the two components of reliability and efficacy. Reliability is defined as the probability that the system operates on demand and efficacy is defined as the degree to which a system achieves its objective given that it does operate. The conclusions reached for each of these events are summarised in Table 2. The events described below are sequential and not time dependent. A description of event 7 was omitted but is the same as, and is included in, Determinations 2005/134, 2005/168, and 2005/169.

Table 2 Events Probability

Event	Description	Probability
4	Occupant awake	The probability assumption is a Normal distribution with a mean of 0.79 and standard deviation of 0.08.
6	Sprinkler system effective	For both Building A and Building B, the efficacy is 0.95 with a Uniform reliability varying function over the range 0.94 to 0.97
7	Automatic alarm	The efficacy is taken as 0.90 with the reliability as a normal distribution with a mean of 0.90 and a standard distribution of 0.05
8, 9, 10	Barrier effective	For Buildings A and C (both lightweight partitions), the efficacy is 1.00 with a Uniform reliability distribution over the range 0.48 to 0.68.
11	Pressurisation effective	The efficacy is 0.90 with a uniform reliability distribution from 0.50 to 1.

6.3 Consequences of Each Scenario

6.3.1 Up to this point, the analysis has considered, via the event trees, sequences that lead to credible scenarios and the **probabilities** that these scenarios will occur. The experts' report then begins the task of calculating the **consequence** of each scenario by undertaking a time dependent analysis. Given a particular scenario, the probability of a negative escape time margin is calculated as a function of Available Safe Egress Time (ASET) vs. Required Safe Egress Time (RSET).

6.3.2 The following definitions apply:

Available Safe Egress Time

The available safe egress time is the time between the start of a fire and the time to the onset of untenable conditions, ie the time to when escape is no longer deemed possible.

The mathematical expression for ASET is:

$$ASET = S \times U_S$$

Where S is the time to untenable conditions, and U_S is an uncertainty factor.

Required Safe Egress Time

The required safe egress time is the time that is actually needed for the occupants to evacuate to a place of safety.

The mathematical expression for RSET is:

$RSET = t_d + t_i + t_r + t_e$

Where:

t_d is the time to detection:

- t_i is the investigation time
- t_r is the occupant response time
- t_e is the occupant movement time

The required result for a safe building is that ASET is greater than RSET so that the available safe egress time is longer than the time for the occupants to escape before untenable conditions are experienced.

6.4 Calculation of risk

6.4.1 The partial risk for the range of credible scenarios identified in an event tree presented in the report is calculated by multiplying the cumulative probability of that scenario by its severity. The severity is the probability of a negative escape time margin multiplied by the number of people exposed. Then the partial risk for each scenario is summed.

6.4.2 The calculation of total risk is complex. For this analysis a computer programme (@RISK) was used. The analysis is probabilistic, using stochastic rates rather than discrete values, using a Monte-Carlo calculation engine to compute the values.

6.5 Risk evaluation

6.5.1 The experts' report notes that the risk evaluation criterion is comparative-probabilistic. The risk profiles of the two buildings are directly compared, and Building A is deemed to succeed where "the risk profile is less than that that of Building C, with the inclusion of an acceptable safety margin". The "individual risk of fatality" is the risk measure used in the experts' analysis and was also applied in Determinations 2005/109, 2005/134, 2005/168, and 2005/169.

6.5.2 This assessment assumes that injury is proportional to fatality. This means that if Building A has a lower risk of fatality than Building C the injury rate is also lower. The assessment does not include events that might have occurred prior to the fire event in an apartment. The unit of risk is not related to frequency and the measure of risk is not a complete profile. However, the experts noted that this approach is deemed valid in terms of a comparative analysis.

6.6 Results

6.6.1 General

6.6.1.1 The results from the experts' analysis of Building A in comparison to the C/AS1 compliant Building C are depicted as risk profiles and margins, and are given graphically in Figure 4 (below). The x-axis is a measure of risk and the dimension is the risk of fatality given a developed apartment fire. The y-axis measures the probability density.

6.6.1.2 The graphs are generated from the outputs from the @RISK computer programme. The risk profiles of the two buildings for both Case 1 and Case 2 from the @RISK computer analysis are overlaid on each other to show the risk profiles of the buildings in relation to each other. In order to indicate that Building A has a lower risk in the event of fire than Building C, the risk profile for Building A should sit to the left of the corresponding profile of Building C. The second graph shows the risk margin, and is the net risk profile of Building C minus the net risk profile of Building A. The results show that there is a risk margin of 0% for Case 1 and a risk margin of 96% for Case 2, which has the addition of a corridor pressurisation system .

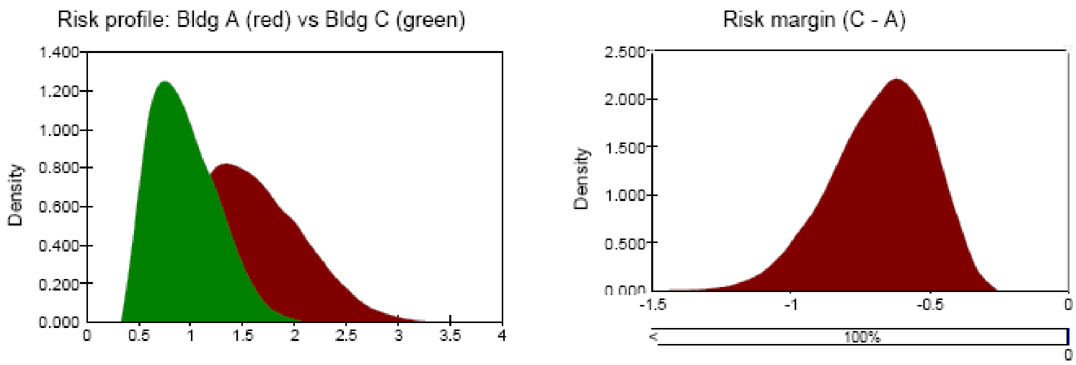

Figure 20: Case 1 "As submitted" (a) Risk profile and (b) Risk margin (0%), the x-axis is risk of fatality given an apartment fire

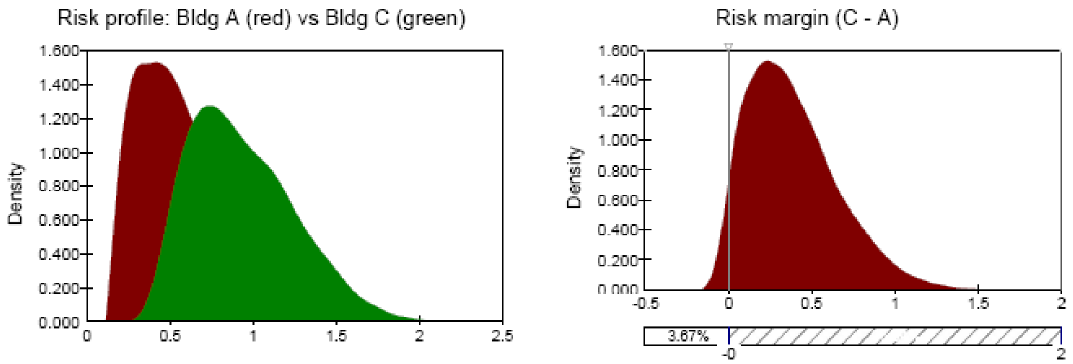

Figure 21: Case 2 "As recommended" (a) Risk profile and (b) Risk margin (96%), the x-axis is risk of fatality given an apartment fire

Figure 4. Risk comparison of Building C and Building A.

6.6.1.3 These results show that Case 1 as submitted in the fire reports does not pass the comparative evaluation analysis, while the experts' recommended Case 2 scenario does.

6.6.1.4 The experts also carried out a sensitivity analysis of the Case 2 risk profiles for both Building A and Building B. The programme used takes in individual input values, increases it by a relative amount, such as its standard deviation, and measures the impact on the output. This is repeated in the programme across all inputs and results are normalised. The experts were surprised that in both profiles the risk is more sensible to the fire than to the sprinkler system. The experts gave reasons for this result but noted that, while the barrier seriously affected both profiles, they do so in equal proportions. However, the impact and importance of the corridor pressurisation system is a more important factor.

6.6.1.5 The experts noted that the results include the safety margin that the risk (C - A) >0. However, as Case 1 clearly fails and Case 2 clearly passes, the experts did not discuss this margin in detail.

6.7 Outcome

6.7.1 The experts' report concluded that, in their view, and subject to some specific conditions, there were reasonable grounds to assume that their proposed alternative solution for Building A is code-compliant. The conditions were that:

- a corridor pressurisation system is to be designed, installed, and commissioned to the satisfaction of the territorial authority, with particular attention paid to air relief
- doors are not to be locked from the stairwell side in a manner that would prevent occupants from being able to enter any floor level from the stairwell in fire alarm conditions
- in the absence of automatic smoke detectors, tamper-proof manual-call points are to be provided in the stairwells
- appropriate signage is to be included to the satisfaction of the territorial authority, indicating that the escape route descends past the ground floor entry in each tower to the first basement level
- the fire engineer is to monitor construction and provide a "Producer Statement of Construction Review" to the satisfaction of the territorial authority.

(Note: I reiterate the point that the Building A relates to the Waverly Tower, which was analysed as being exemplar, but that these conditions apply equally to both Waverly and Turner towers as described by the expert.)

6.8 Comments on experts' report by the parties

6.8.1 Copies of the experts' report were provided to each of the parties. The territorial authority and the applicant accepted the report without comment.

6.8.2 The Fire Service, by an e-mail dated 24 February 2006, made a number of comments on the experts methodology, recording in particular its view that:

> "analysis of major departures from the Approved Documents must be assessed by quantitative risk assessment techniques", but "the chief drawback associated with this technique at present is the lack of adequate data as noted in paragraph 6.2.5 of Determination 2005/109, and quoted by the independent expert".

6.8.3 With regard to the process of establishing the probability that the alternative solution (Building A) is at least as safe as the Acceptable Solution (Building C); it said:

> "[g]iven the uncertainty in the assumed data, this amounts to an attempt to establish the confidence or margin associated with an assertion that the alternative design is at least as

safe as a compliant design. The experts report appears to suggest that the recommended design has a 96% probability of complying with the Building Code, which appears to be acceptable. However, there are a few issues with the assumed escape scenario. The expert has assumed that everyone attempts to escape as soon as the alarm is raised. Can the expert confirm that if occupants choose to stay in their apartments, they are at no greater risk than they would be in a building that complies with the Approved Documents?"

6.8.4 With respect to the "arson scenario", it states:

"Single means of escape buildings are more vulnerable than buildings with two stairways to an arson attack, or other fire, in the stairway… It is of particular concern that the sophisticated analysis carried out by the expert has shown that people are not safe from smoke logging if they try to escape though a stairway that has been the subject of an arson attack, even though the stairway is open to air on one side. This should be brought out very clearly in the determination as a warning against engineers making subjective judgments as to how smoke will behave without carrying out the analysis. The fire in the staircase scenario should have been integrated into the risk analysis, modifying the calculated 'margin'."

6.8.5 With regard to "passive fire safety systems", it recommends that:

"Given the reliance on fire resisting barriers in the design, conditions should be placed on any building consent relating to inspection during, and on completion of, construction. Final inspection should be conducted by a suitably qualified expert and documentation requires as to the integrity and construction methods for all fire barriers. This should be made explicit in the conditions listed at 11.2 of the report"

6.8.6 With regard to "active fire systems", it recommended that:

"…the compliance schedule for the building includes an appropriate testing and inspection regime complying with relevant standards for all active systems to ensure ongoing compliance…" and noted that they supported the approach I had taken in Determination 2005/109."

7 Discussion

7.1 General

7.1.1 I have considered the submissions of the parties, the experts' report and subsequent submissions and the other evidence presented in this matter. The approach in determining whether building work complies with clauses C2 and C3 is to examine the design of the building and the design features that are intended to prevent the loss of life. I have described this process previously in Determination 2005/109, which addressed a similar matter, and I have taken that material into account in this Determination.

7.1.2 Of the comments of the Fire Service I make the following points. On the question of the margin, I discuss this later. Regarding the arson scenario, I note the comments of the Fire Service on the desirability of the inclusion of the arson scenario (or fires from any other cause outside of an apartment) within the main risk analysis. I agree with those comments in the long run. However, at this stage, there is limited data to allow these to be included directly in such analysis. At the current stage of knowledge, I believe the "one off hazard check" is the best means of analysing the risk of fires from these causes. I do endorse the need for these scenarios to be considered and the need for engineers to properly analyse the effects of smoke behaviour.

7.2 Are the buildings code compliant?

7.2.1 I have considered the comparative analysis undertaken by the experts, alongside the other information provided to me about the buildings, and note the following:

7.2.2 The experts have indicated a comparative margin in the base case plus the inclusion of a corridor pressurisation system of 96%, which clearly exceeds a target range of 50% to 75%, set by other determinations, such as Determination 2005/109 *et al*.

7.2.3 There are a number of issues to be evaluated in determining whether the building is code compliant or not. Firstly, there is the question of the comparative probabilistic risk assessment and its results. More specifically, what does it mean and how does it relate to other compliance measures? Secondly, there is the consideration of the on-going compliance of this building with the Building Code.

7.2.4 Whilst this current result is, on the face of it, superior to that reported earlier for the building described in Determination 2005/109, that of itself is not sufficient to provide me with reasonable grounds on which to decide compliance. It is clear that, taken overall, the safety of occupants within a building of this type hangs on whether the most critical compensation component, namely the pressurisation system, is well designed and robust. This is clearly a first order effect, to be evaluated before efficacy and reliability tests are applied.

7.2.5 With regard to the probabilistic risk assessment, in previous determinations, the experts have recommended that I accept 75% as the threshold for the margin. To put it another way, this means that there should be a 25% increase in probability that the alternative building will be better than the compliant building. This extra buffer is required in part because the actual probability distribution may not be a pure random variable as assumed in the experts' analysis. As noted in the Fire Service's comments, more analysis is required before a numerical value can be described to an appropriate margin. Even once one has been developed, this will not take away the need for other factors such as the quality of the overall fire design to be factored into the acceptance criteria.

7.2.6 As discussed in paragraph 5.9.1.1, the design as proposed by the applicant (not the base case) has a margin of 0%. Clearly this is not acceptable as it falls short of the 75% threshold. However the expert has analysed the base case of a compliant building with a corridor pressurisation system that provides a margin of 96% which is acceptable. I also note that the experts assume, as set out in paragraph 5.3.3, that if The Waverly tower is found to be code-compliant, then it follows that the Turner tower is also code compliant. I accept this contention.

7.2.7 I note also that the experts' analysis as undertaken for this building relates only to a multi-unit residential dwelling corresponding to Purpose Group SR of the current Acceptable Solution C/AS1.

7.3 "Protect in place" strategy

7.3.1 This building as proposed in the consent documentation has a "protect in place" strategy. This means that occupants in apartments will be held in their apartments while the Fire Service fights the fire. The safe egress evaluation conducted by the experts was based on a total (one-out all-out) evacuation and concluded that the design was sufficient before "protect in place" concepts needed to be incorporated.

7.3.2 The experts said in their report:

> "The impact of the Type 8 voice communication system is not quantified in this analysis, as "protect in place" evacuation strategies are not currently widely accepted, and certainly not in single escape route buildings."

Their other comments relating to evacuation issues are documented in paragraph 5.4.

7.3.3 These comments need to be clarified. I concede that there are two different concepts to consider. The first is that of "protect in place" strategies. The second is the technology to deliver that strategy. In this case, the technology includes a voice communication system (Type 8), which allows the fire fighters to communicate directly with occupants.

7.3.4 What "not quantified" means is that analysis of the required safe egress time did not include any time delay arising from occupants being held in their apartments. Similarly, the greater consequence was not applied On one hand this makes the analysis conservative in that it assumes that maximum occupancy in the stairwell thereby raising the overall risk. Conversely, it is less conservative in that non-tenable conditions may be created before the Fire Service call for full evacuation.

7.3.5 I am aware that there are arguments for and against the appropriateness of "one-out all-out" and "protect in place" fire egress strategies for apartments. The relative merits of the two strategies also change when considering either single or multiple egress buildings or specialised situations such as hospitals or prisons. There is a view that until such time as research, technology and building practices prove otherwise, the occupants should be evacuated from a single means of escape building in the most expedient and timely manner, i.e. "one-out all-out". This is also consistent with behaviour of people exposed to fires in New Zealand, which historically is for people to want to evacuate as soon as an alarm is sounded. The counter view is that a "protect in place" strategy gives the fire fighters the ability to evacuate people as and if required, thereby minimising the possibility of evacuated or evacuating occupants disrupting fire fighting. It also minimises disruption to those not affected by a fire or even a false alarm. The Type 8 system (the "technology") has merit as it allows for direct communication with apartment occupants.

7.3.6 As discussed above, the "protect in place" concept is not one I believe was contemplated by the Acceptable Solution C/AS1, nor I would suggest, by provisions C2 and C3 of the Building Code itself.

7.3.7 In my view, the objective of the "means of escape" provision within clause C2 of the Building Code is clearly to "safeguard people from injury or illness from a fire whilst escaping to a safe place". Clause C2 of the Building Code defines a "safe place" as a place of safety in the vicinity of a building from which people may safely disperse after escaping from the effects of fire. It may be a place such as a street, open space, public space, or an adjacent building.

7.3.8 Consequently, if a "protect in place" concept was to be relied on in this building as a primary means of ensuring safety of building occupants, then a modification of Clause C2 would be required, solely on the grounds that the safeguards put in place to protect people from the effect of fire were not aimed at achieving exit to a safe place.

7.3.9 In Determination 2005/134 and subsequent determinations, I left the option open to the owner to either elect to stay with the proposed strategy or revert to a “one-out all out” system. Should the evacuation strategy be “protect in place”, then I requested that a modification to the building code be sought. In that instance, the building had already been constructed and there were neighbouring buildings in the same complex (with the same management systems) that had been completed and occupied on the basis of “protect in place” strategies.

7.3.10 Those circumstances don’t apply in this case. The building is not built and it is not part of a complex. I am of the view that it should have a total evacuation strategy, which is, I believe, the strategy required by the Building Code. However, the benefits that the technology brings should not be ignored and the Type 8 system should be retained to allow communication between the fire fighters and the occupants. This would also facilitate the use of a “protect in place” strategy should this receive endorsement in the future.

7.3.11 The experts have also commented that the doors are not be locked from the stairway side in manner that would prevent occupants from being able to enter any floor level from the stairway in fire alarm conditions. This, in effect, enables a “safe refuge” concept to be added as an enhancement feature to the basic fire safety design already evaluated, thereby contributing to the overall robustness of the design and shall be adopted.

7.3.12 The single means of escape from fire Determinations have drawn the issue of evacuation strategies into sharper focus and work is now proceeding to develop a view as to the appropriateness of “protect in place” evacuation strategies, particularly in single means of escape buildings.

8 Ongoing Compliance

8.1 As noted in paragraph 6.2.3, the pressurisation system is critical to the overall effectiveness of the fire safety systems in the building. Accordingly, it is important that the system be maintained and monitored to a high standard. For this to occur, the compliance schedule needs to include a specific requirement for on-going testing of the system. Determination 2005/109 provides a useful template for an appropriate schedule. I do not expect that the inspections, the maintenance standard, the person responsible and the additional requirements will be to a lower standard than was applied in that case.

8.2 As noted in 6.7.1, the expert also recommended a condition be included ensuring that the doors are not be locked from the stairway side in manner that would prevent occupants entering any floor level from the stairway in fire alarm conditions. This is an important feature that needs to be carried through in the detail design of the building systems and their consequential commissioning. In addition, there should also be an inclusion in the compliance schedule to ensure the systems are tested during the building warrant of fitness checks, appropriate signage is to be provided and the construction is to be monitored by the fire engineer..

9 Conclusion

9.1 I consider that the design as proposed in the consent documents does not comply with the Clauses C2 and C3 of the Building Code.

9.2 However I am satisfied, based on the information provided, that if the work outlined in the decision below is designed and installed to an appropriate standard, and if certain other conditions are met, it is possible for The Waverly tower to become code compliant. I also accept the experts' opinion that if The Waverly tower is code compliant then so is the Turner tower with the same conditions applied.

9.3 I also consider that the building should not have a "protect in place evacuation" strategy as these strategies are still not established as being appropriate in single means of escape buildings in New Zealand.

9.4 It is emphasised that each Determination is conducted on a case-by-case basis. Accordingly, the fact that a particular design or system has been established as being code compliant in relation to a particular building does not necessarily mean that the same system will be code compliant in another situation.

9.5 I decline to incorporate any waiver or modification of the Building Code in this case.

10 The decision

10.1 In accordance with section 188 of the Act;

(a) I determine that the building work as proposed does not comply with Clauses C2 and C3 of the Building Code.

(b) I also find that a building meeting the following conditions is likely to meet the requirement of the fire clauses of the Building Code provided it is used as a multi-unit residential dwelling corresponding to Purpose Group SR of the current Acceptable Solution C/AS1. These conditions are all subject to the territorial authority being satisfied on reasonable grounds that they have been met. I draw to the territorial authority's notice to the comment made by the experts and the additional requirements to these as set out below:

i. A corridor pressurisation system is to be designed, installed, and commissioned to the satisfaction of the territorial authority, with particular attention paid to air relief.

ii. Doors are not to be locked from the stairwell side in a manner that would prevent occupants from being able to enter any floor level from the stairwell in fire alarm conditions.

iii. In the absence of automatic smoke detectors, tamper-proof manual call points are to be provided in the stairwells to facilitate fire alarm operation and re-entry.

iv. Appropriate signage is to be included to the satisfaction of the territorial authority, indicating that the escape route descends past the ground floor entry in each tower to the first basement level.

v. The work outlined in the architect's submission is to be carried out in totality, together with the supply of appropriate producer statements.

vi. The evacuation strategy is a "total evacuation" system.

vii. The compliance schedule for the building shall define escape route compliance, performance, and monitoring standards I will also take note of the Fire Service's recommendation that the compliance schedule includes an appropriate testing and inspection regime complying with the relevant standards for all active systems, to ensure ongoing compliance of the building.

(c) I require the territorial authority to provide me with a report within two months of issuing the compliance schedule confirming that these conditions have been met.

Signed for and on behalf of the Chief Executive of the Department of Building and Housing on 1 June 2006.

John Gardiner
Determinations Manager

Appendix A: Floor plans of the two adjoining towers