MRTFC

MULTI-RESIDENTIAL
TIMBER FRAMED CONSTRUCTION

Class 2 & 3 Buildings

STRUCTURAL ENGINEERING GUIDE

National Timber Development Council

STRUCTURAL ENGINEERING GUIDE
FOR CLASS 2 AND 3 BUILDINGS UP TO 3 STOREYS
(4 storeys where ground floor is masonry for car parking)

NATIONAL TIMBER DEVELOPMENT COUNCIL

FOREST & WOOD PRODUCTS
RESEARCH & DEVELOPMENT CORPORATION

PREFACE

This publication is intended to complement a range of other literature published by the Forest and Wood Products Research and Development Corporation (FWPRDC) and Standards Australia and should be read in conjunction with these publications.

The aim of this publication is to provide notes and criteria applicable to the structural design of Class 2 and 3 Buildings up to 3 Storeys in height (for Class 2 Buildings, up to 4 Storeys where the ground floor is for car parking and is constructed in masonry or concrete).

This publication which is written in limit state format is primarily intended for use by structural engineers.

Other publications complementary to the use of this publication include the following:-

AS 1170	Loading Code – Standards Australia
AS 1684.1	Residential timber-framed construction. Part 1: Design Criteria – Standards Australia
AS 1720.2	Timber Structures. Part 1 – Design methods
AS 1720.4	Timber Structures. Part 4 – Fire-resistance of structural timber members
MRTFC -	Design and construction manual for Class 1 Buildings – National Timber Development Council FWPRDC
MRTFC -	Design and construction manual for Class 2 and 3 Buildings - National Timber Development Council FWPRDC
MRTFC –	Information Bulletin No. 5 – Fire and Sound Rated Wall and Floor/Ceiling Summary - National Timber Development Council FWPRDC

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Introduction

Since MRTFC was introduced in Australia in 1996 its acceptance and use is now widely acknowledged as a very economical and efficient form of construction for Class 1, 2 and 3 buildings. More economical fire and sound rated timber wall and floor/ceiling systems are being tested and certified to facilitate this form of construction and to improve efficiencies. Construction details also continue to be refined and improved to support the value of MRTFC.

Class 2 and 3 timber framed buildings differ in their design considerations from normal domestic Class 1 buildings in a number of aspects including dead and live loads, structure stability (increased height), fire and sound ratings, and the general philosophy and reliability associated with design. These guideline notes and criteria have therefore been prepared to assist engineers in the structural design of these buildings.

Scope

This publication provides guidelines and notes to assist engineers performing structural calculations and checks on timber framed Class 2 and 3 buildings up to 3 storeys in height (four storeys where the ground storey is of concrete/masonry construction).

It is not intended that they replace or negate the engineers need or responsibility to make reference to the appropriate loading and material standards or building regulations.

The guidelines given are intended to highlight some of the structural design considerations that may be new or not familiar to engineers who regularly work with timber in domestic construction only (Class 1 buildings) or for those who usually design in other construction materials.

Structural Considerations

Although many aspects of the design of single detached timber framed dwellings may be applied to Class 2 and 3 buildings, it is necessary, particularly for 3 and 4 storey timber framed buildings, to consider the implications of design criteria and loads that are specific to this form of construction.

Generally these buildings in timber are:

- of lighter mass than full masonry construction
- relatively tall and slender
- required to carry greater dead loads (fire and sound rated walls and floors) and live loads than Class 1 buildings
- required to accommodate larger numbers of people
- constructed using specific methods for attachment of linings to achieve fire and sound ratings.

These differences give rise to a number of structural considerations above those applicable to normal domestic construction or alternatively that may vary from multi-storey masonry construction. The following provides some guidance on these aspects.

Designing for Shrinkage

(Where unseasoned timber is used)

Note: In general, the use of unseasoned timbers in 2 or 3 storey construction should be limited to minimise shrinkage problems.

Shrinkage considerations for multi-residential construction are similar to normal domestic construction except, for 2 and 3 storey buildings the potential for greater total shrinkage must be considered where unseasoned timber is used together with the effect shrinkage may have on the integrity of fire and sound rated walls and floors.

When designing for shrinkage the following should be considered:-

- reduce overall shrinkage
- avoid differential shrinkage
- provide clearances to brickwork and masonry and allow for shrinkage with respect to plumbing.

Total shrinkage will vary markedly depending upon the combinations of wall and floor frame selected and the building practice adopted.

Potential problems that can be associated with shrinkage can be minimised or eliminated through:-

- limiting the use of unseasoned hardwood for wall framing only, in buildings of one or two storeys
- use of seasoned or engineered products for joists in lieu of unseasoned timber.
- reduce one level of shrinkage by using joists and bearers in line (joists supported off bearers using framing brackets)
- use of seasoned wall and floor framing throughout
- eliminating differential shrinkage
- making allowance for "calculated" shrinkage relative to clearances to masonry or other freestanding elements

Building Mass

Full timber framed construction (including masonry veneer) using timber framed floors, walls and roofs has a mass of less than one-half of that of full masonry construction (with timber roof frame).

Whilst this affords considerable savings in minimising the depth, breadth and reinforcing required in footings, the effect of a lower building mass also impacts upon the structures overturning stability. This design consideration is discussed later.

Foundations and Footings

AS 2870 Residential Slabs and Footings, provides general guidance for detached residential construction of up to two storeys. Some additional limitations apply where first floors are of suspended slab construction. These standards are therefore generally applicable to Class 1 buildings of up to two storeys, however for timber framed Class 2 and 3 buildings they would also be applicable for up to two storeys. For 3 and 4 storey timber framed construction, footings should be designed in accordance with AS 3600 Concrete Structures or if required AS 2159 Piling – Design and installation.

Structure Stability

As is shown in Table 1 - (Dead Load Column), full timber framed multi-residential construction has much less mass than traditional full masonry. In addition, this type of multi-residential construction often has end elevations which are "slender", with typical height to width ratios of around 1.5:1. The narrower the width of these buildings and the greater the design wind speed the more that overturning of the structure becomes critical as a structural design consideration.

It is recommended that an engineering check of overturning be carried out where the wind velocity (Vu, ultimate limit state) exceeds 50 m/s and or the height to width ratio exceeds approximately 1.5:1.

Typical Design Loads

- **Dead and Live Loads**
  AS 1170.1 and AS 1170.2 provide the basis for determination of appropriate dead, live and wind design loads and load combinations applicable to Class 2 and 3 multi-residential construction. A summary of some typical loads are given in Table 1 and, where appropriate for comparative purposes the corresponding loads for full masonry construction i.e. floors and walls are shown alongside. More detailed dead loads for walls, roofs and floor/ceilings are given in Tables 2 and 3.

  Earthquake forces can be determined from AS 1170.4 and these are described in more detail later. For alpine and sub-alpine areas snow loads in accordance with AS 1170.3 should also be considered.

- **Wind Loads**

  Building height is a significant input for determination of design wind speed. For 3 or 4 storey construction, the additional storey height/s could be expected to increase the design wind velocity normally associated with two storey construction by around 8 to 10% (at a particular site). This increase in velocity will increase design wind pressures by about 15-20%, which when coupled with increased DL's associated with fire rated construction could significantly effect member design when compared to normal Class 1 buildings. For 3 or 4 storey construction, these effects must be considered usually requiring specific engineering design of members etc.

  For 3 or 4 storey construction in built up non-cyclonic areas, (terrain category 3, no topographic effects) typical ultimate limit state design wind speeds would be around 50 m/s. These of course may be able to be reduced for the lower levels of the building.

  Typical lateral wind forces for an ultimate limit state design wind speed of 50 m/s are provided in Table 4 for 3 or 4 storey multi-residential construction.

  As can be seen from Figure 1, lateral wind forces on lower storeys, for relatively low design wind velocities, are quite high and will need to be resisted by 'significant' bracing walls as is shown in the example in Figure 1.

  For higher or lower design wind speeds, the lateral forces increase or decrease in proportion to the square of the velocity.

  For wind blowing normal to the width of the building, similar forces per unit width would apply except for buildings with gable or skillion ends where a slight increase will apply to account for the increased flat area of wall. This can be determined by reference to AS 1170.2

TABLE 1 TYPICAL DESIGN LOADS (UNFACTORED) FOR CLASS 2 AND 3 BUILDINGS (Ultimate limit state design wind speed 50 m/s – Non-cyclonic areas)

Element	Load Type	Dead Load[1],[4]			Live Load [2],[4]	Wind Load[3],[4]
		Timber Frame Construction		Full Masonry/ Concrete		
Roof (Includes roofing, framing and fire rated ceiling)	UDL (kPa)	Sheet Roof 0.55	Tile Roof 1.05	-	$\left(\frac{1.8}{A}+0.12\right)$ or 0.25	1.7
	Concentrated (kN)	-	-	-	1.4[6]	-
Walls - External (lining, frame and 110 mm brick)	Line load (kN/m)	2.4xheight (m) (0.7 if lightweight clad)		4.2	-	1.5
- Internal	Line load (kN/m)	(0.45 - 0.55)xheight (m)		2.1	-	-
Floors (Including fire rated ceiling) - General Areas	UDL (kPa)	1.1 - 1.4		4.0[5]	2.0	-
	Concentrated (kN)	-		-	1.8	-
- Hallways, Passages etc.	UDL (kPa)	1.1 - 1.4		4.0[5]	4.0	-
	Concentrated (kN)	-		-	4.5	-
Balconies	UDL (kPa)	1.1 - 1.4		4.0[5]	4.0	-
	Concentrated (kN/m)	-		-	1.5 (live load on edge of balcony)	-

Notes:

1. The floor DL's given include an allowance of 0.5 kPa for that portion of floor live load considered permanent.
2. Refer to AS 1170.1 for possible floor live load reduction factors.
3. Wind loads given are typical gross ultimate limit state pressures normal to the relevant surface. For lateral wind forces refer to Table 4. For Regions A and B typical ultimate limit state design wind speeds of between 45 and 53 m/s are appropriate for buildings to 15 m high in Terrain Category 3.
4. The loads shown above are "unfactored". The determination of "Limit State" design load combinations must be done by reference to Table 5
5. Concrete floor mass based on 150 thick slab plus covering.
6. For Class 1 buildings. AS 1684.1 specifies a concentrated load of 1.1 kN.

TABLE 2 TYPICAL DEAD LOADS OF FIRE AND SOUND RATED WALLS

Wall	FRL	System	Dead Load (kPa)
External			
Brick Veneer	60/60/60 both directions	110 mm brick + single stud + fire rated lining (note: mass of brick veneer not included)	0.2
	90/90/90 from outside in	110 mm brick + single stud + fire rated lining (note: mass of brick veneer not included)	0.2
	90/90/90 both directions	110 mm brick + single stud + fire rated lining (note: mass of brick veneer not included)	0.3
Clad Wall	60/60/60 both directions	Lightweight cladding + fire rated sheeting + single stud + fire rated plasterboard lining	0.5
	60/60/60 both directions	Lightweight cladding + fire rated sheeting + single stud + fire rated plasterboard and fibre cement lining	0.7
	90/90/90 both directions	Lightweight cladding + fire rated sheeting + single stud + fire rated plasterboard and fibre cement lining	0.7
Internal			
	60/60/60	Single, staggered or double stud wall + fire rated plasterboard lining + insulation	0.4
	60/60/60	Single stud wall + fire rated plasterboard and fibre cement lining + insulation	0.5
		Staggered stud wall + fire rated plasterboard and fibre cement lining + insulation	0.55
		Double stud wall + fire rated plasterboard and fibre cement lining + insulation	0.6
	90/90/90	Single stud wall + fire rated lining + insulation	0.5
		Staggered stud wall + fire rated lining + insulation	0.55
		Double stud wall + fire rated lining + insulation	0.6

TABLE 3 TYPICAL DEAD LOADS FOR FIRE AND SOUND RATED ROOFS AND FLOOR/CEILINGS

Element	FRL	Roofing/flooring	System	Dead Load (kPa) [1]
Roof and Ceiling				
Ceiling	60 minutes RISF	N/A	fire rated ceiling lining	0.25
Roof and ceiling	60 minutes RISF	Sheet roof	Sheet roof + framing + fire rated ceiling	0.55
		Tile roof	Tile roof + framing + fire rated ceiling	1.05
Floor/Ceilings				
General areas	30/30/30	Timber flooring + Carpet and underlay	Flooring + joists + fire rated lining on resilient mounts	0.5
		Timber flooring ceramic tiles and underlay	Flooring + joists + fire rated lining on resilient mounts	0.7
	60/60/60	Timber flooring	Flooring + joists + fire rated lining on resilient mounts	0.65
		Timber flooring + Carpet and underlay	Flooring + joists + fire rated lining on resilient mounts	0.7
		Timber flooring ceramic tiles and underlay	Flooring + joists + fire rated lining on resilient mounts	0.85
	90/90/90	Timber flooring	Flooring + joists + fire rated lining on resilient mounts	0.7
		Timber flooring + Carpet and underlay	Flooring + joists + fire rated lining on resilient mounts	0.75
		Timber flooring ceramic tiles and underlay	Flooring + joists + fire rated lining on resilient mounts	0.9
Balconies	60/60/60	Timber Flooring	Flooring + joists + fire rated lining	0.65
		Timber flooring ceramic tiles and underlay	Flooring + joists + fire rated lining	0.85

Note :
An additional allowance of approximately 0.5 kPa should be added to the dead loads of floor systems to account for the permanent proportion of floor live loads. Refer to Load Combinations.

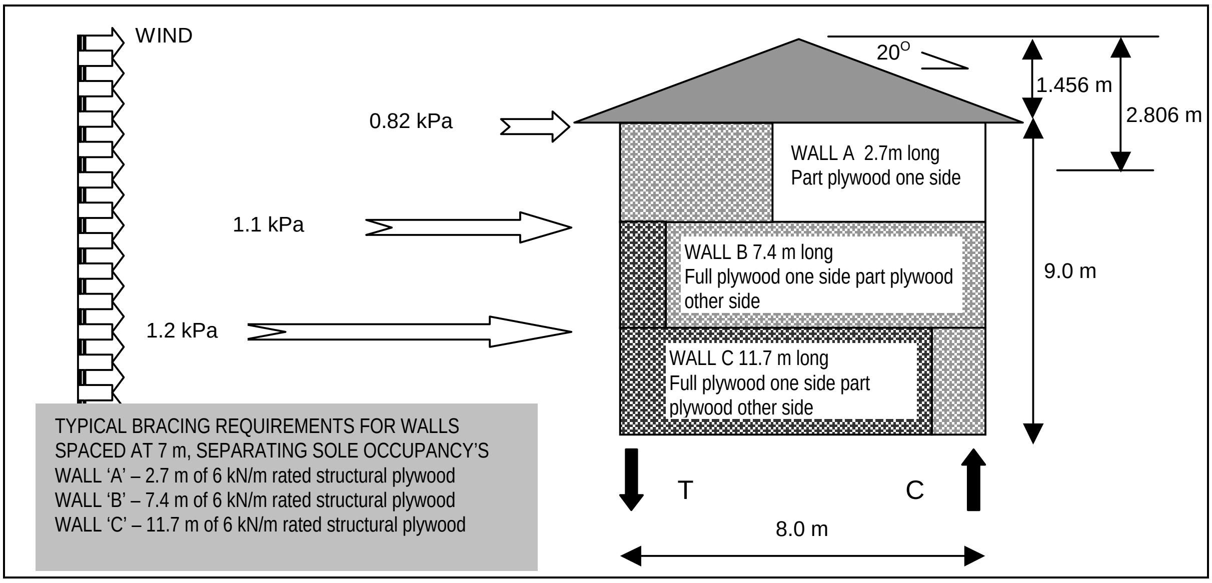

FIGURE 1 EXAMPLE OF "BRACING" FORCES FOR ULTIMATE LIMIT STATE WIND SPEED 50 m/s

Example

Wall A - Top level: From Table 4, wind pressure = 0.82kPa
Area of elevation = height of elevation x brace wall spacing
Height of elevation=½ wall height+roof height=2.7/2+1.456 =2.806 m, brace wall spacing = 7 m
Therefore Racking force on wall A (@ 7m spacing) = 0.82kPa x 2.806 x 7m = 16.1 kN
Since Wall A has 6kN/m bracing capacity, the length of braced wall required = 16.1/6 = 2.7m

TABLE 4 TYPICAL LATERAL WIND FORCES ON A 4 STOREY MULTI RESIDENTIAL BUILDING (Ultimate limit state design wind speed of 50 m/s)

Level of Building	Building Width (m)	Wind Pressure 'p' (kPa) on elevated area of building. Values in bracket are Wind Force 'F' (kN/m) per unit length of building					
		Roof Slope (Degrees)					
		5	10	15	20	25	30
Top level	6	1.1 (1.8)	0.98 (1.8)	0.87 (1.9)	0.89 (2.2)	1.1 (3.0)	1.2 (3.6)
	8	1.0 (1.8)	0.91 (1.9)	0.79 (1.9)	0.82 (2.3)	1.0 (3.3)	1.1 (4.2)
	10	1.0 (1.8)	0.85 (1.9)	0.74 (2.0)	0.82 (2.6)	1.0 (3.8)	1.1 (4.7)
	12	0.95 (1.8)	0.79 (1.9)	0.70 (2.1)	0.85 (3.0)	1.0 (4.3)	1.1 (5.3)
3rd level	6	1.2 (5.7)	1.2 (5.8)	1.1 (5.8)	1.1 (6.1)	1.3 (7.3)	1.3 (7.9)
	8	1.2 (5.7)	1.2 (5.8)	1.1 (5.9)	1.1 (6.3)	1.2 (7.6)	1.3 (8.5)
	10	1.2 (5.7)	1.1 (5.8)	1.0 (5.9)	1.1 (6.6)	1.2 (8.1)	1.2 (9.0)
	12	1.2 (5.7)	1.1 (5.9)	1.0 (6.0)	1.1 (7.0)	1.2 (8.6)	1.2 (9.6)
2nd level	6	1.3 (9.7)	1.2 (9.8)	1.2 (9.8)	1.2 (10)	1.3 (12)	1.3 (12)
	8	1.3 (9.7)	1.2 (9.8)	1.2 (9.8)	1.2 (10)	1.3 (12)	1.3 (13)
	10	1.2 (9.7)	1.2 (9.8)	1.1 (9.9)	1.1 (11)	1.3 (12)	1.3 (13)
	12	1.2 (9.7)	1.2 (9.8)	1.1 (10)	1.1 (11)	1.3 (13)	1.3 (14)
Ground level	6	1.3 (14)	1.3 (14)	1.3 (14)	1.2 (14)	1.4 (16)	1.3 (16)
	8	1.3 (14)	1.3 (14)	1.2 (14)	1.2 (14)	1.3 (16)	1.3 (17)
	10	1.3 (14)	1.2 (14)	1.2 (14)	1.2 (14)	1.3 (16)	1.3 (17)
	12	1.3 (14)	1.2 (14)	1.2 (14)	1.2 (15)	1.3 (17)	1.3 (18)

Notes:

1. The floor to floor height assumed in the above table is 3.0 m (2.7m wall height and 0.3m floor depth).
2. The force per unit length of building can be determined by multiplying the pressure kPa by the height of elevation at the desired level.

- **Earthquake Loads**

  AS 1170.4 "Minimum Design Loads on Structures - Earthquake Loads", provides guidance and design procedures to cater for earthquake forces on multi-residential construction.

  Multi-residential construction up to 3 or 4 storeys is classified as a Type 1 Structure under this code and as such, Earthquake Design Category A, B or C would apply depending upon the product of the acceleration co-efficient and site factor (a.s.). Where the soil profile for a site is unknown, a "default" site factor of 1.5 should be applied. For most major Australian cities, this gives rise to a Design Category A or B which would not require a static analysis of the forces acting on the building as timber framed structures are classified ductile. One exception to this is in Category B for irregular buildings (either geometry, centre of mass or bracing resistance) which would require static analysis.

  For cases that require static analysis, the shear forces can be determined from Section 6 of AS 1170.4 and resistance to these shear forces detailed similar to the wind loads.

  Note:
  Unlike wind forces (that are a function of area of elevation), earthquake forces are a function of building mass. Therefore earthquake forces do not decrease (as normally occurs with wind) normal to the width of the building. For long slender buildings, earthquake forces may dictate shear (bracing strength) requirements parallel to the building length.

Shearwalls and Diaphragms

Three storey Class 2 and 3 buildings can be constructed using conventional "domestic" framing techniques which rely upon the structural action of horizontal diaphragms and vertical shearwalls in combination to resist lateral and overturning loads. These systems provide the inherent strength for this 3 dimensional "cubicle" form of construction.

For multi-storey construction, the need to resist lateral wind or earthquake forces increases with the height of the building, and as mentioned previously, overturning may also need to be considered.

Design procedures for shearwalls and diaphragms are published in the NAFI Timber Manual - Datafile SS6 (See references). In addition, most sheet manufacturers have relevant design data published giving shear or bracing capacities for their products.

Note:
The information given in NAFI Datafile SS6 is in permissible stress format and will have to be converted to limit state format to be compatible with this publication. This may also be true for some manufacturer’s shearwall or diaphragm information.

Some shearwall and diaphragm design considerations that need to be addressed for up to 3 storey Class 2 and 3 buildings are as follows :-

- allowing for secondary stresses in shearwall or diaphragm chord members (studs and plates). These stresses, either tension or compression, result from the bending action induced in the shearwall or diaphragm plus the shear due to lateral forces. Studs can be designed in compression for the combined DL plus chord compression stress due to wind or earthquake forces. For wind/earthquake tension stresses, tie-down bolts can be installed for the full height of the walls as well as for connecting storeys. Alternatively, studs can be designed in tension.

- many fire and sound rated wall and floor/ceiling systems rely upon resiliently mounted sheeting (usually plasterboard) for noise control purposes. Unless these systems have been specially rated, the bracing or diaphragm capacity of the system should be ignored as there is no direct rigid connection to the framing.

- normal sheet flooring directly fixed to joists will provide sufficient diaphragm action to transfer lateral loads between shearwalls walls spaced up to 14 m provided:-
  i) the floor diaphragm span to depth ratio does not exceed about 2:1.
  ii) the ultimate limit state design wind speed does not exceed 50 m/s.

- during construction, sufficient permanent bracing must be installed in the lower levels of the building (a minimum of 60% of the total permanent bracing is suggested) prior to the upper levels being framed up or the roofing installed. This requirement caters for the fact that wind and gravity forces are usually as high during construction as at completion, as well as the fact that construction loads are often eccentric (stacked flooring, lining and roofing materials).

- check resistance of tie-down fixings for shear loads, particularly in the lower levels as lateral loads may be quite significant.

Member Design

For Class 2 and 3 Buildings, specific engineering design of the structural framework should be carried out using the relevant loading codes and AS 1720.1 "Timber Structures – Part 1:Design methods", as the basis of design.

AS 1684.1 “Residential timber-framed construction, Part 1:Design criteria”, whilst specifically written to for Class 1 Buildings, can also be used as a general guide for the design of members in Class 2 and 3 Buildings provided the appropriate adjustments are made to the relevant criteria, including:-

- Dead Loads - Due to fire and sound rating requirements these are usually much greater than traditional domestic construction due to the extra sheeting and insulation required.

- Live Loads - AS 1170.1 specifies higher levels of live load (floors in particular) for Class 2 and 3 Buildings.

- Wind Loads - Care needs to be taken to ensure that the correct design wind speed is determined due to the increased height of 3/4 storey buildings (the terrain category/height multiplier will be greater than normally determined for two storey Class 1 Buildings resulting in higher pressures on members).

- Load Combinations – AS 1170.1 details the relevant load combinations that are required to be considered in design. The general load combinations given for the framing members in AS 1684.1 for Class 1 Buildings are also applicable to members in Class 2 and 3 Buildings however the additional load combinations given in AS 1170.1 for earthquake and fire may also be relevant to the design of some members and may need to be considered.

Because of the higher load levels expected with Class 2 and 3 Buildings, and the use of conventional member sizes, specific checks should also be carried out on stresses perpendicular to grain e.g. studs bearing on plates and in some instances tension perpendicular to grain etc. Refer to AS 1720.1.

Some specific loading considerations for various members are as follows:-

- **Roof and Ceiling Framing**

i) Dead Loads are increased due to the normal requirement of providing a ceiling with 1 hour resistance to incipient spread of fire i.e. 2 layers of 16 mm fire resistant plasterboard equals 0.25 kN/m² (approx.) vs 0.1 from normal domestic design. Refer to Table 3.
ii) For suspended or resiliently mounted ceilings, the loadsharing capacity of the system (k_9, AS 1720) may not be as great as for direct fixed ceilings. This may also effect lateral restraint assumptions (k_{12}).
iii) Wind loads may be greater than normal due to increased height of building.

- **Wall Framing**

i) For walls required to be fire rated, increased dead loads due to the additional weight of either one or two layers of fire rated board need to be considered in addition to the heavier mass of any fire rated overlying ceilings, walls and floors. Except in external brick veneer walls, these layers will usually be required both sides of the wall increasing the wall DL's up to about 0.7 kPa. Refer to Table 2.

ii) For lower storey loadbearing walls, higher uniformly distributed floor Live Loads of 2.0 or 4.0 kPa may need to be considered alone or in combination with other live and wind loads and also higher floor dead loads (to cater for fire rated ceilings to the underside of the floors).
Note:
AS 1170.1 permits live load reduction factors to be applied to members supporting areas in excess of 23.0 m². For some lower storey loadbearing wall members this reduction may be applicable.

iii) Wind loads on walls may also be greater due to increased height of the building.

- **Floor Framing**

i) Floor dead loads will be increased due to the need to provide additional sheeting and insulation to the floor/ceiling system to cater for sound and fire rating requirements.

Typical DL's of around 0.7 kPa to 0.9 kPa are suggested to cater for flooring, insulation, joists and ceiling lining, refer to Table 3. In addition, a percentage of the floor live load should be added to the DL to account for that portion of floor live load that is permanent. In AS 1684.1, the dead load of the floor has been increased by 0.5 kPa to account for this and this is also considered appropriate for the general floor areas of Class 2 and 3 Buildings.

ii) AS 1170.1 specifies floor live loads for Class 2 and 3 Buildings of 2.0 and 4.0 kPa for general areas and hallways etc. respectively compared to Class 1 Buildings of 1.5 kPa. These UDL's for Class 2 and 3 Buildings have corresponding point live loads of 1.8 kN and 4.5 kN that also have to be considered independently. Live loads on balconies are specified as 4.0 kPa or 1.5 kN/m along the edge of the balcony.

iii) Floor vibrations have been demonstrated to be of concern for typical lightly loaded domestic Class 1 Building floor framing systems and a design check has been included in AS 1684.1 to cater for this. For Class 2 and 3 buildings with higher floor dead and live load requirements, dynamic effects may not be as critical as member sizes may be controlled by these other load considerations. Irrespective, it is still recommended that the serviceability check for vibration given in AS 1684.1 be carried out.

Load Combinations and Deflection Limits

A summary of some typical load combinations and deflection limits that may be considered in the design of some members for Class 2 and 3 buildings is given in Table 5. It should be noted that these load combinations are applicable to limit state design.

TABLE 5 TYPICAL LOAD COMBINATIONS AND DEFLECTION LIMITS (Limit State Design)

Member	Strength	Deflection Limits		
	Load Combinations	Load Type	Ratio	Max (mm)
Rafters, Roof Beams etc.	$1.25G_1$ $1.25G_1 + 1.5Q_1$ $1.25G_1 + 1.5Q_2$ $0.8\ G_1 + W\uparrow$ $1.25G_1 + W_\downarrow$	G_1 Q_2 W_s	$\Delta_1 \le L/300$ $\Delta_2 \le L/250$ $\Delta_3 \le L/150$	
Ceiling Joists, Hanging Beams	$1.25G_1$ $1.25G_1 + 1.5Q_2$ $0.8\ G_1 + W\uparrow$ $1.25G_1 + W_\downarrow$	G_1 Q_2	$\Delta_1 \le L/400$ $\Delta_2 \le L/270$	12
Wall Studs - Top Storey Loadbearing	$1.25G_1$ $1.25G_1 + 1.5Q_1$ $1.25G_1 + 1.5Q_2$ $1.25G_1 + k_c\ (W_\downarrow + W_\rightarrow)$ $0.8\ G_1 + k_c\ (W\uparrow + W_\rightarrow)$ $W_\rightarrow$	W_s	$\Delta_3 \le L/150$	20
- Lower Storey Loadbearing	$1.25G_2$ $1.25G_1 + 1.5Q_3$ $1.25G_1 + 1.5Q_4$ or $1.25G_1 + 1.5Q_5$ $0.8\ G_2 + k_c\ (W\uparrow + W_\rightarrow)$ $1.25G_2 + k_c\ (W_\downarrow + W_\rightarrow)$ $W_\rightarrow$	W_s	$\Delta_3 \le L/150$	20
Non-Loadbearing	$1.25G_1 + W_\rightarrow$ (where $W_\rightarrow$ = 0.5 kPa as a "serviceability" component)	W_s = 0.5 kPa	$\Delta_3 \le L/360$ (for brittle surface finishes e.g tile)	8 (for brittle surface finishes e.g tile)
Wall Plates - Top Storey Loadbearing	$1.25G_1$ $1.25G_1 + 1.5Q_1$ $1.25G_1 + 1.5Q_2$ $1.25G_1 + W_\downarrow$ $0.8\ G_1 + W\uparrow$	G_1 Q_2	$\Delta_1 \le L/200$ $\Delta_2 \le L/200$	3 3
- Lower Storey Loadbearing	$1.25G_2$ $1.25G_1 + 1.5Q_3$ $1.25G_1 + 1.5Q_4$ or $1.25G_1 + 1.5Q_5$ $1.25G_2 + W_\downarrow$ $0.8\ G_2 + W\uparrow$	G_2 $\Psi_s\ Q_{3,4,5}$	$\Delta_1 \le L/200$ $\Delta_2 \le L/200$	3 3
Lintels - Top Storey	$1.25G_1$ $1.25G_1 + 1.5Q_1$ $1.25G_1 + 1.5Q_2$ $1.25G_1 + W_\downarrow$ $0.8\ G_1 + W\uparrow$	G_1 Q_2 W_s	$\Delta_1 \le L/300$ $\Delta_2 \le L/250$ $\Delta_3 \le L/200$	10 15
- Lower Storeys	$1.25G_2$ $1.25G_1 + 1.5Q_3$ $1.25G_1 + 1.5Q_4$ or $1.25G_1 + 1.5Q_5$ $1.25G_2 + W_\downarrow$ $0.8\ G_2 + W\uparrow$	G_2 $\Psi_s Q_4$	$\Delta_1 \le L/300$ $\Delta_2 \le L/250$	10 15
Floor Joist - Floor Loads Only	$1.25G_2$ $1.25G_1 + 1.5Q_3$ $1.25G_1 + 1.5Q_4$ or $1.25G_1 + 1.5Q_5$ $1.25G_1 + 1.5Q_6$	G_2 Q_4 $\Psi_s Q_6$	$\Delta_1 \le L/300$ $\Delta_2 \le L/360$ $\Delta_3 \le L/180$* *L = overhang	15 9 4.5 (2mm max under 1 kn point load refer AS 1684.1)

Notes to Table 5:

G_1	=	Sum of all relevant dead loads as appropriate to member under consideration.
G_2	=	G_1 + 0.5 kPa (where 0.5 kPa is an allowance for the permanent proportion of floor live load)
Q_1	=	$\left\{\frac{1.8}{A}+0.25\right\}$ kPa roof live load where A = contributing area m²
Q_2	=	1.4 kN or 4.5 kN concentrated live load as appropriate
Q_3	=	1.8 kN or 4.5 kN concentrated floor live load as appropriate
Q_4	=	2.0 kPa or 4.0 kPa uniformly distributed floor live load as appropriate
Q_5	=	4.0 kPa partial area floor live load on balconies A ≤ 10 m²
	=	3.0 kPa partial area floor live load on balconies 10 < A ≤ 40 m²
Q_6	=	1.8 kN/m along edge of balcony
Ψ_s	=	load factor for short term serviceability live loads
	=	0.7 except that resultant for floor live loads should not be less than 1.8 kN concentrated load or 1.5 kPa uniformly distributed load.
$W_{\uparrow}$	=	Nett upward wind load
$W_{\downarrow}$	=	Nett downward wind load
$W_{\rightarrow}$	=	Nett horizontal wind load
W_s	=	Serviceability Wind Load
$\Delta 1, \Delta 2, \Delta 3$	=	Deflection Limits

Load Capacity of Fire Rated Wall and Floor/Ceiling Systems

Generally tested or certified fire rated loadbearing wall and floor/ceiling systems are required to sustain the normal structural loads and fire load conditions.

Wall and floor/ceiling systems detailed in Information Bulletin No 5 Wall and Floor/Ceiling Summary have been designed, unless otherwise indicated, that the structural load condition governs. For these wall or floor/ceiling system, there is no need to undertake a fire load condition check.

Additionally, for floor/ceiling systems there are no limit in the joist system that can be used. Nail plated timber, I beams, floor trusses can substitute solid timber.

Effective Height of Fire Rated Walls

The effective height used to calculate the load capacity of a fire-rated wall is the distance between points of effective lateral restraint (usually provided by floors and ceilings).

Effective lateral restraint can be provided by:-

1. a floor or ceiling system in an adjoining unit or dwelling (can be lower or non fire-rated)
2. a fire-rated floor/ceiling system within the unit or dwelling under consideration
3. a purpose designed and fire-rated lateral restraint system

NOTE:-
The leaves of double stud wall systems can be effectively tied together at their top and bottom using galvanised iron straps nailed to plates at 1.2 m centres.

Fire Ratings for Solid Timber

There will be some applications of exposed timber members (beams, columns etc) occurring in multiple dwelling construction which require a Fire Resistance Level to be determined for solid timber. In these instances the only FRL relevant relates to structural adequacy.

AS 1720 "Timber Structures Code Part 4: Fire Resistance of Structural Timber Members" is referenced in BCA as an acceptable procedure for calculating FRL's for solid or glued-laminated timber.

The following worked example provides guidance on the application of these procedures.

EXAMPLE:	**A loadbearing internal column in Class 2 or 3 Type "B" Construction**	**REFERENCE**
Requirement:	**FRL 60/60/60 Note: For a column not incorporated in a wall this becomes FRL 60/-/-**	
Assume:	**The column supports a floor above of 10 m² and the column is 2.4 m high**	
Loads:	**Live load, Q = 2.0 kPa : Dead load, G = 1.0 kPa**	**AS 1170.1 - 1989**
	Note DL = Flooring + Joists + Ceiling + Insulation etc.	
	Limit State Design Load for Fire; $W_{LSD} = 1.1G + \Psi Q$ **$W = W_{LSD}$** **For G = 1.0, Ψ = 0.4, Q = 2. 0** **$W_{LSD} = 1.1G + \Psi Q$ = 1.9 kPa** **W* = 1.9 x10 = 19 kN**	**Cl 2.5 AS 1170.1 – 1989** **Cl 2.8 AS 1720.4 –1990**

CALCULATIONS	**REFERENCE**
1st Approximation: Assume F17 glued-laminated seasoned hardwood $\phi N_c = k_1 k_4 k_6 k_9 k_{11} k_{12} (f'_c A_c)$	 Cl 3.3.1.1 AS 1720.1
where:- $\phi = 0.85$ k_1=0.94 f'_c=40 MPa k_4=k_6=k_{11}=1.0, k_{12}=0.3 assumed Equate W* = N_c = 0.85x0.94x0.3x40xA_c = 9.59 A_c Therefore:- 19kN = 9.59A_c Hence, $A_c = \frac{19x10^3}{9.59} = 1982$ mm² equals approximately 45x45mm Assume a 70x70mm cross section of solid timber remains after the fire event. A_c = 4900 mm²	 Table 2.5 AS 1720.1 Table G1 AS 1720.1 Table 2.4 AS 1720.1

Check cross section for fire limit state load of 19 kN $\phi N_c = \phi k_1 k_4 k_6 k_{11} k_{12}(f'_c A_c)$ Where:- $\phi = 0.85$ k_1=0.94 f'_c=40 MPa $k_4=k_6=k_{11}$=1.0 For k_{12}, S3= $\frac{g_{13}L}{d}$ Where g_{13} = 0.75, L = 2400 and d = 70mm S3= $\frac{0.75x2400}{70}$ = 25.7 ρ = 1.13 for seasoned F17 ρS_3 = 25.7x1.13 = 29 Therefore $K_{12} = \frac{200}{(\rho S)^2} = \frac{200}{(29)^2}$ = 0.24 And ϕN_c = 0.85x0.94x 0.24x40x4900 = 37.6 kN > 19 kN $\therefore$ OK **Determine effective depth of charring** Effective depth of charring d_c = ct + 7.5 Where t = time = 60 mins for FRL 60/-/- and c = 0.4 + $\left(\frac{280}{\rho}\right)^2$ Where ρ = timber density @ 12% moisture content For Jarrah = 800 kg/m^3 and Blackbutt = 900 kg/m^3 Use ρ = 800 kg/m^3	Table 3.3 AS 1720.1 Cl 2.5 AS 1720.4

Other Considerations

- For glued laminated timber, the glue used for lamination must be of the resorcinol or phenolic types in accordance with AS 1328

- Post connections must also be detailed to achieve the FRL required. This can be achieved by:-

i) Using a standard timber bearing joint with nominal connection for lateral displacement - this is quite suitable for compressive loads.

ii) Protection of the joint using fire resistant materials. (Refer AS 1720.4, Cl 3.2)

References

1. BUILDING CODE OF AUSTRALIA
Australian Building Codes Board - Canberra, ACT. 1994

2. AS 2870 - RESIDENTIAL SLABS AND FOOTINGS
Standards Australia - Sydney, NSW.

3. AS 3600 - CONCRETE STRUCTURES
Standards Australia - Sydney, NSW.

4. AS 2159 - PILING CODE
Standards Australia - Sydney, NSW.

5. AS 1170.2 - LOADING CODE - WIND LOADS
Standards Australia - Sydney, NSW.

6. AS 1170.1 - LOADING CODE – DEAD AND LIVE LOAD COMBINATIONS
Standards Australia - Sydney, NSW.

7. AS 1770.4 - LOADING CODE - EARTHQUAKE FORCES
Standards Australia - Sydney, NSW.

8. AS 1684.1 – RESIDENTIAL TIMBER-FRAMED CONSTRUCTION. PART 1 DESIGN CRITERIA
Standards Australia - Sydney, NSW.

9. TIMBER MANUAL
National Association of Forest Industries Canberra Australia 1989

10. AS 1720.1 TIMBER STRUCTURES CODE, PART 1, DESIGN METHODS
Standards Australia, Sydney, NSW.

11. AS 1720.4 TIMBER STRUCTURES CODE, PART 4 FIRE RESISTANCE OF STRUCTURAL TIMBER MEMBERS
Standards Australia, Sydney, NSW. 1994

12. FIRE RESISTANCE OF TIMBER FRAMED FLOORS AND WALLS - TR 93/5
Building Technology Limited/CSIRO Division of Building Construction and Engineering, CSIRO North Ryde, NSW. 1993.

13. MRTFC DESIGN AND CONSTRUCTION MANUAL FOR CLASS 2 AND 3 BUILDINGS
National Timber Development Council, Forest and Wood Products Development Corporation, Melbourne Victoria 2000

14. MRTFC INFORMATION BULLETIN NO 5 – WALL AND FLOOR CEILINGS SYSTEM SUMMARY
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