holmesglen

CPC50210 Diploma of Building and Construction (Building)

CPCCBC4010B

Apply structural principles to residential low-rise constructions

Learner Resource

Version: VI-1

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Acknowledgements

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Contents

Introduction to unit CPCCBC4010B

Welcome to the Learner Resource for *CPCCBC4010B Apply structural principles to residential low rise constructions*. This unit forms part of the CPC50210 Diploma of Building and Construction (Building), which is a qualification designed to meet the needs of builders and managers of small to medium-sized building businesses.

The builder may also be the appropriately licensed person with responsibility under the relevant building licensing authority in a particular state or territory. Builder licensing varies across states and territories, so additional requirements may be required to become licensed in the particular state or territory.

Occupational titles may include:

- builder
- construction manager.

This unit of competency specifies the outcomes required to apply structural principles to the erection or demolition of low rise residential structures using conventional methods. The unit addresses those structures classified by the Building Code of Australia as Classes 1 and 10. Knowledge of the application of structural principles in accordance with the Australian Standards is essential.

This unit of competency supports the needs of builders, site managers, forepersons and other managers in the building and construction industry responsible for overseeing and managing the demolition or erection of structures.

A copy of the full unit of competency is included in Appendix 3 of this Learner Resource together with a list of all the units required to complete the CPC50210 Diploma of Building and Construction (Building).

Note: The unit of competency in this Learner Resource was current at the time of publication.

References

This Learner Resource is to be used with reference to other texts, such as the Building Code of Australia and Australian Standards. These will be included in the printed materials provided.

About this course

This Learner Resource is one of a set of resources that you will use to complete the CPC50210 Diploma of Building and Construction (Building).

Flexible delivery

This Learner Resource is used to provide you with everything you need to complete this unit. You are about to embark on a type of training that is called flexible learning, which means that you do not need to attend formal classes.

Flexible learning is a good option for this level of learning as it allows you to undertake the course at your own pace and in your own time. When undertaking flexible learning it is important to:

- set and document clear timelines to read and understand a topic and to complete all the learning activities and assessment tasks
- be motivated and don't let distractions impact on your progress
- undertake one topic at a time. You should work through the topics in the order they are presented in this Learner Resource
- submit your assessment tasks on or before the due date and time
- not wait until you finish all the reading and learning activities before you attempt the assessment tasks – undertake them when you feel you are confident about the topics they address
- make sure the assessment task that you send to be assessed is clearly labelled by completing and attaching the assessment task cover sheet with your name, assessment task title, date, etc.

What you will study

The Learner Resource has two parts that you should work through step by step:

- Part 1 contains information about the structural principles used to perform a range of calculations in the building and construction industry.
- Part 2 contains information about the application of structural principles in the context of residential low rise constructions. Throughout the section, there are a number of learning activities that you are required to complete. These are provided to help you apply and reinforce what you have learnt in each section. If you have trouble answering any of them, contact your tutor. There is also one assessment task associated with this section.

Icons

The following icons are used throughout this Learner Resource.

	Learning activity These activities help you consolidate your learning and may be used to build a portfolio of evidence.
	Assessment task These must be submitted to your tutor and will be used to assess your knowledge and skills in each competency.
	Information Note or key points are used to alert you to additional information or critical points that need to be understood.

Your time commitment

It should take about 160 hours to complete this unit. However, depending on your circumstances or prior knowledge, you may find that it takes a little less or more time to finish the work.

Activities and assessment

Throughout this Learner Resource there are activities to help reinforce the learning associated with a new topic. Your tutor may require you to forward your responses to these activities to them as part of your formal assessment. If this is required you will be advised by your tutor. The assessment tasks are provided at the back of this Learner Resource.

The assessment tasks can be attempted as you work through the Learner Resource. You don't have to wait until you have completed all the activities before attempting an assessment task.

There are five assessment tasks for this unit that you must submit to your tutor on or before the agreed date and time. The titles of the assessment tasks are:

1. Evaluation of demolition for residential low rise construction
2. Plan the construction project
3. Evaluate structural elements
4. Construction systems (structural components)
5. Construction systems (non-structural components)

Make sure that all work you submit is your own and that you appropriately acknowledge and reference source materials. When you have completed an assessment task, send it to your tutor who will assess your work and provide appropriate feedback about whether you have satisfied the requirements of the assessment task. If you have any questions about your assessment results please contact your tutor.

Satisfactory completion of the unit

You will be deemed competent for this unit on the basis that you can provide evidence of:

- assessing the structural integrity of a variety of structures found on building and construction sites
- applying the structural principles behind the safe erection and demolition of a low rise structure classified within the Building Code of Australia as Classes 1 and 10
- applying technical construction principles to the appropriate selection, integration and building in of construction elements and components
- coordinating, planning, implementing and checking the building of a low rise structure.

Employability Skills

Employability Skills are the generic skills required not only to gain employment but also to progress within the workplace. These skills help you to achieve your potential and to successfully contribute to the strategic directions of an organisation or your business.

Employability Skills are embedded within every competency and included in all assessments. The Employability Skills within this unit are presented in a table in Appendix 1 of this Learner Resource, mapped against the assessment activity that addresses the skill.

Getting started

It’s now time for you to start working through this Learner Resource. We wish you all the best with your study in this unit and all the other units required to complete the CPC50210 Diploma of Building and Construction (Building).

Remember, if you have any questions about your study please contact your tutor for clarification.

PART 1

Introduction

This Learner Resource, ‘CPCCBC4010B, Part 1’, addresses Element 1 of the unit of competency *CPCCBC4010B Apply structural principles to residential low rise constructions*.

To obtain competency in CPCCBC4010B, you must complete both the CPCCBC4010B, Part 1 and Part 2 Learner Resource for this unit of competency.

1. Basic structural principles

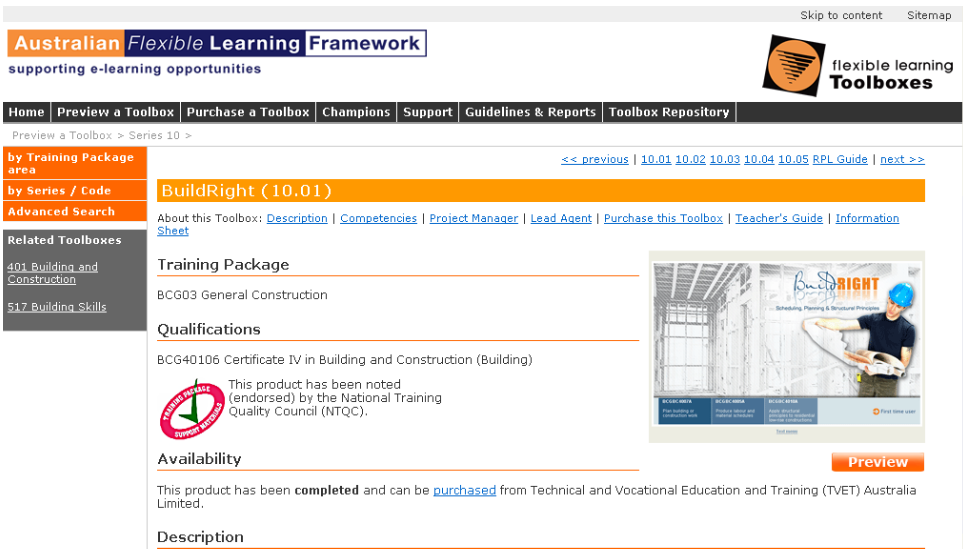
You will need to use the following resource to complete this activity:

- CD-ROM – BuildRight Toolbox –
  BCG03 General Construction Training Package
  BCG40106 Certificate IV in Building and Construction (Building)

- provided in your materials and shown in this learner resource as images on the following pages.

You are required to:

- work through the entire BuildRight Toolbox CD-ROM and the BCGBC4010A / B – Introduction
- choose one topic in the 'Test your knowledge' section to complete and test your knowledge in the relevant area
- determine how your chosen topic applies to the application of structural principles in residential and commercial low rise constructions.



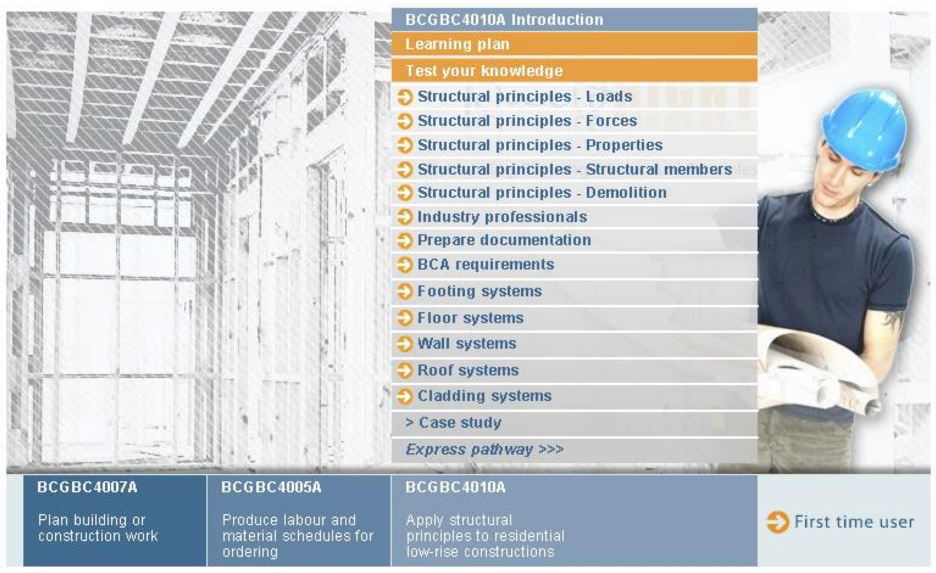
BuildRight Toolbox

Selecting the preview button will display the Toolbox.

Using the BuildRight Toolbox

Accessing BCGBC4010A / B

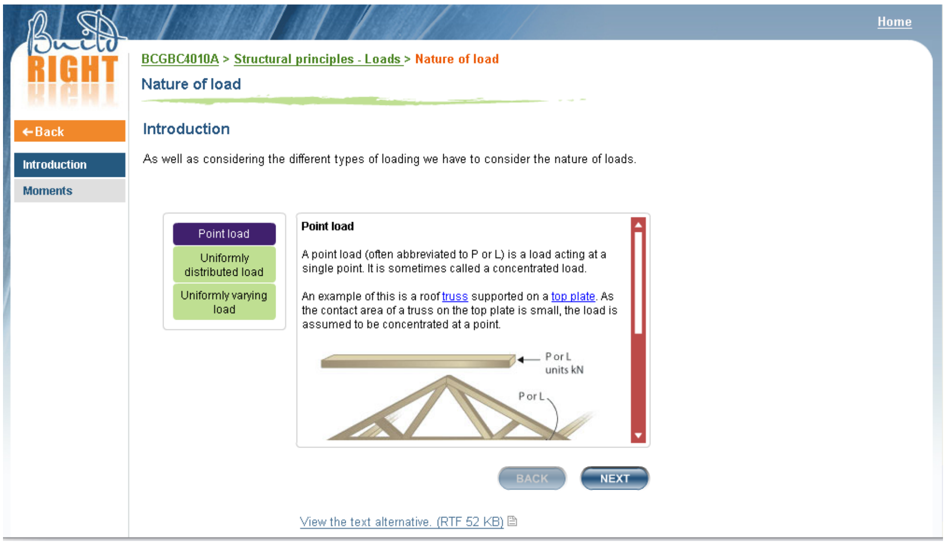
Positioning your mouse over the 'BCGBC4010A' tab brings up the menu as shown below:



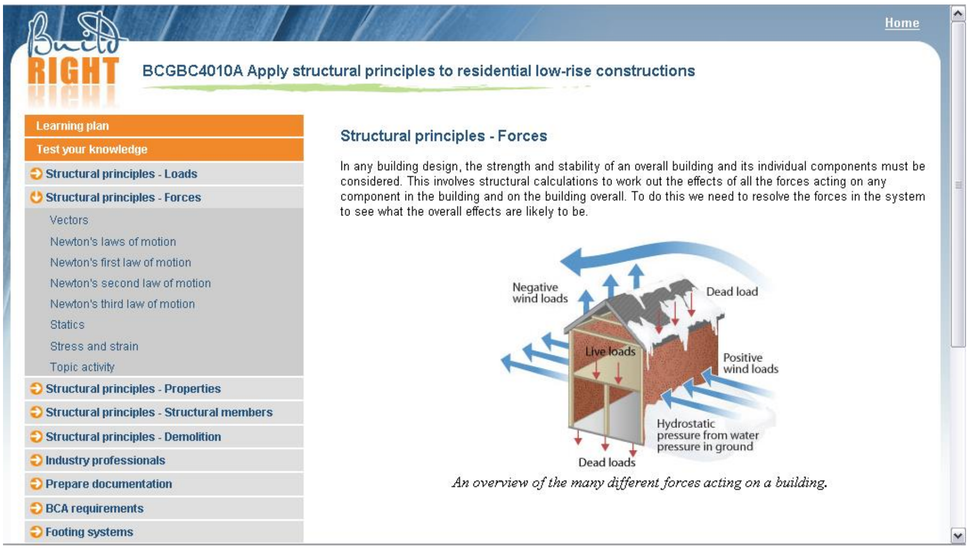
BuildRight Toolbox menu options

Examples of images contained within the BCGBC4010A / B Toolbox

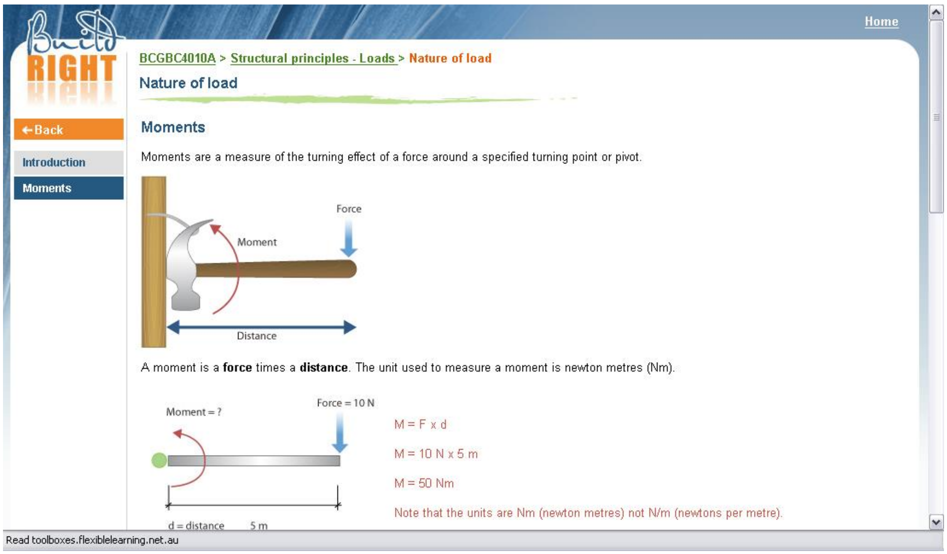
The following images are examples of notes relating to some of the titles on the menu:



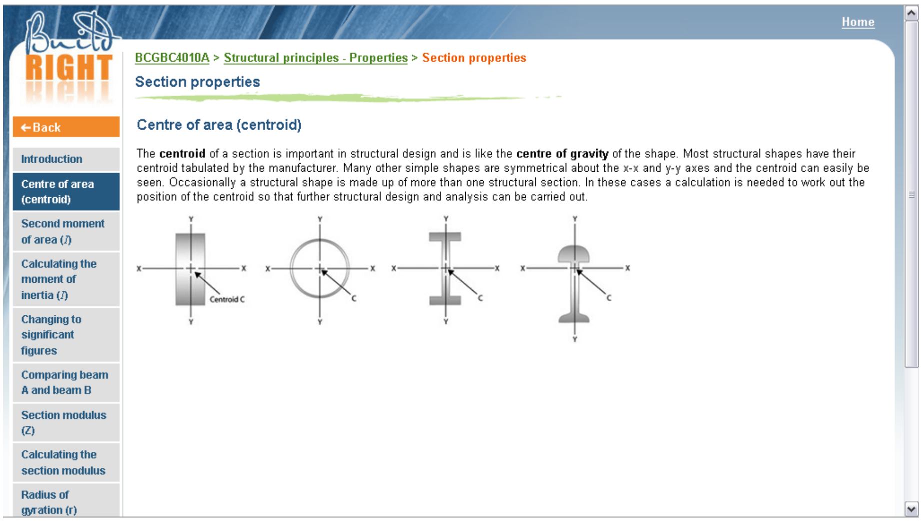
Example 1



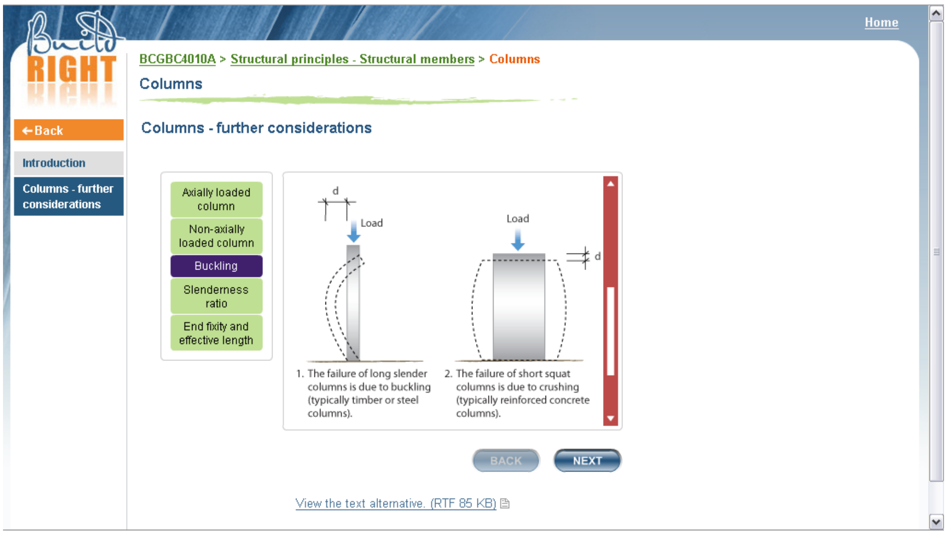
Example 2



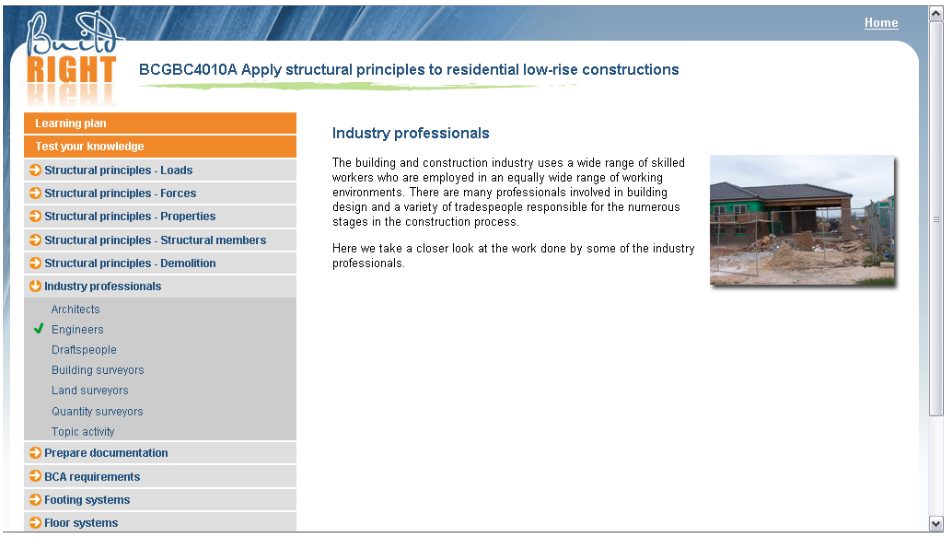
Example 3



Example 4



Example 5



Example 6

In this section we will be looking at the application of the basic structural principles for both residential and commercial low rise constructions.

1.1 Loads and loading

Structural principles fundamentally involve the managing and handling of loads and loading. To understand loading, it is important to define the concept of a load. To ensure safety, a building/structure has to be able to withstand the most severe combination of loads over its lifespan.

Force and gravity are two important terms associated with load. A force is an influence, which tends to cause motion. A force is generally considered to be either a 'pull' or 'push'. Force is a result of the interaction between the two bodies.

Sometimes the force causing (or capable of) motion is the nett or resultant force (R) of a system of forces. If the nett or resultant force is zero (0), then the body is said to be in a state of static equilibrium, that is, there is no motion or no acceleration.

1.1.1 Types of loads

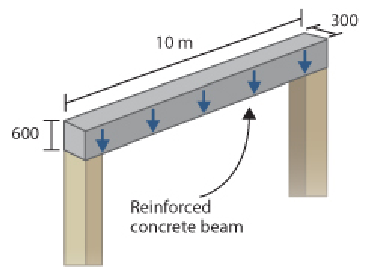
There are essentially three main types of loads:

- Dead loads
- Live loads
- Wind loading

Dead loads

These are loads that are applied continuously throughout the life of the building. They are forces associated with gravity, hence, they are determined mainly by the mass of the materials used in construction.

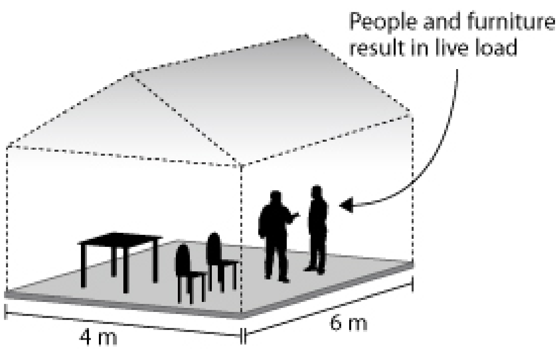
In the following graphic the weight of the beam provides a dead weight to the supporting columns.



Example of a dead load

Live loads

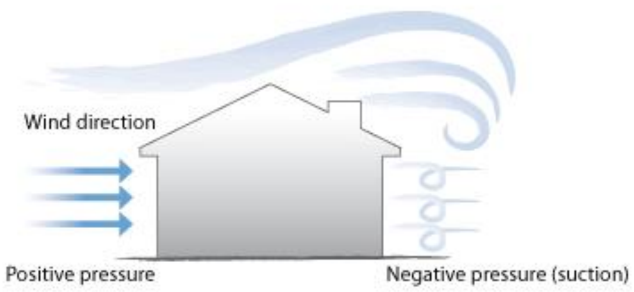
These are loads that change with the operation and activity that occurs within the building.



Example of live load

Wind loading

Wind loads can come in any direction with varying magnitudes. The wind factor can depend on the geographical location of the building.



Example of wind loading

Structures may be subjected to many different types of loads (ie forces). Some examples include wind forces, people in an office, cars in a car park, a heavy piece of machinery on a particular position of a factory floor, snow loading on a roof, earthquake loading, hydrostatic force (due to water pressure).

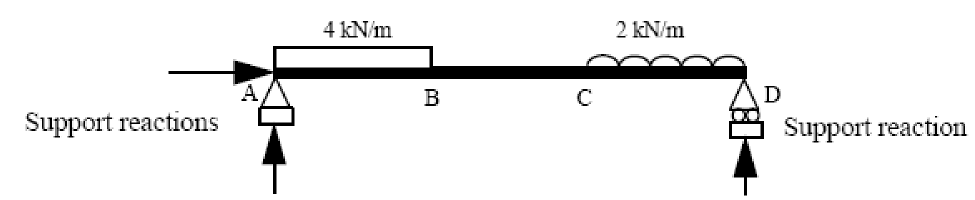
This Learner Resource is only concerned with concentrated loads and uniformly distributed loads.

1.1.2 Concentrated loads

This is defined as a single force acting at a particular point on the structure.

1.1.3 Uniformly distributed load

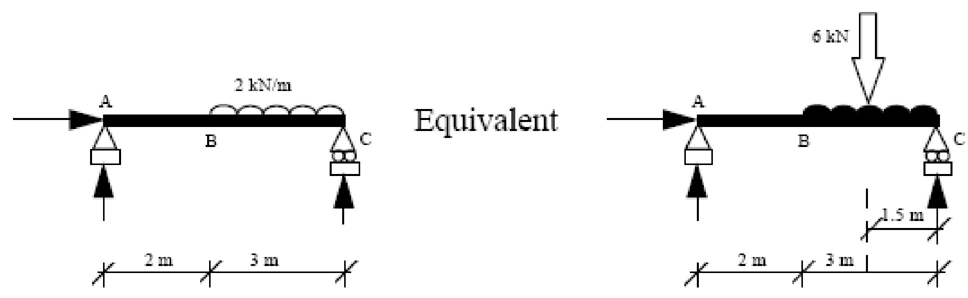
This type of load is one that is uniformly 'spread' over an area or length of the structure the unit of weight of which is usually weight per unit length (ie kN/m).



Example 1 – Uniformly distributed load (UDL)

For the purpose of calculating the reactions of the supports, the UDL is converted to a point load and is considered to be acting (or concentrated), midway along its length.

Consider the equivalent diagrams (in concentrated load form) for the purposes of determining reactions at the supports for the following example.



Example 2 – Uniformly distributed load (UDL)

That is, concentrated load = UDL x length = 2 kN/m x 3 m = 6 kN.

The UDL load is concentrated at midway of its length = 3/2 m = 1.5 m.

If the self weight of the structure is to be considered as part of the calculations for the reactions, then in the case of a beam, the self weight is to be assumed to be a UDL and thus converted to a concentrated load, assumed to be acting at its midspan for the purpose of reaction calculations.

1.2 Measurement and unit of force

Force is measured using the International System of units (the SI system). The SI unit of force is the Newton (N). Force can be derived from Newton's Second Law which states that:

Force = mass multiplied by acceleration

Force = mass x acceleration

F = ma, where F = Force, m = mass and a = acceleration

Therefore by definition, a Newton of force is:

'the unit force required to accelerate a mass of one kilogram at a rate of one meter per second squared'

F = ma → [Newton] = [kg] x [m/sec^2]

Similarly, for weight (W):

W = mass x acceleration

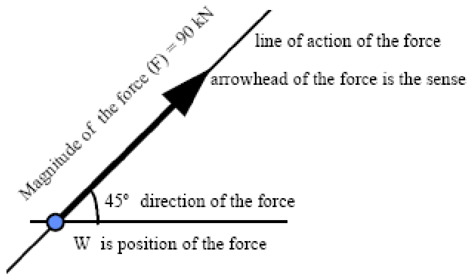
In this case, acceleration = gravitational acceleration (g = 9.81 m/sec^2)

Therefore, to convert mass to weight, multiply the mass with gravity. For example, a mass of 1 kg has the equivalent weight of 9.81 N.

A more realistic and useful unit of force in building and construction is kN, where 1000 N = 1 kN (1 kilo Newton).

1.3 Properties of a force

Force is a vector, it has magnitude, direction, sense and position.



Force

1.4 Basic principles of forces

There are three basic principles associated with force:

1. The principle of action and reaction

   Newton's Third Law states that for every action there is a reaction. This means forces come in pairs. By identifying one force, you can identify the other. In construction, for example, a hammer is a force that comes into contact with a nail, which is driven into the timber.

2. The principle of transmissibility

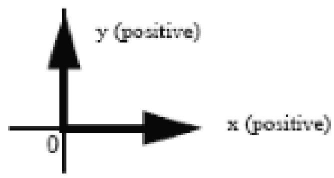
   The effect of an external force on a rigid body remains unchanged if that force is moved along its line of action.

3. The principle of the parallelogram of forces

   Used to calculate the combined effect of two different forces acting together on an object.

1.5 Components of a force

A force can be broken into individual components. In general, they are divided into horizontal and vertical components, where the horizontal direction is designated 'x' and the vertical direction is designated 'y', similar to mathematics.



Components of force

There are two methods generally used in dealing with calculations of components of forces. They are:

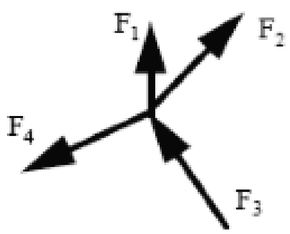
- graphical method
  (ie parallelogram)
- mathematical method
  (resolving forces into 'x' and 'y' components).

1.6 Polygon of forces method

The term 'poly' implies many. Here, forces are combined graphically to form a polygon of forces.

1.7 Equilibrium of concurrent coplanar forces

A concurrent force system is defined as a system of forces whereby the line of action of each force in the system passes through one common point.



Concurrent force system

The section, Loads and loading, it showed that given a system of forces, we can determine that single force, which in effect replaces all of the other forces with respect to magnitude, direction, sense and position. This force is called the resultant, R. There were a number of ways of determining R, they were, for example:

- the parallelogram
- force polygon
- mathematical addition of forces.

If a system of forces has a resultant, then the system must be in motion.

However, since most structures are not in motion, then there cannot be a resultant, ie the resultant force has to equal zero. When this is the case, such structures are said to be 'in equilibrium'.

More specifically, this is known as static equilibrium, which is defined to be 'a state of no motion in any direction'.

It follows then that a state of equilibrium means that there cannot be any resultant force and therefore, it could well be that a force is required to create equilibrium in a force system. This force is known as the equilibrant and is equal in magnitude, but opposite in direction to the resultant.

Previously, the resultant, R, of a force system was found by:

$$R_x = F_{1x} + F_{2x} + \dots F_{nx} = \Sigma F_x$$

$$R_y = F_{1y} + F_{2y} + \dots F_{ny} = \Sigma F_y$$

If a body (or structure) is said to be in equilibrium, there cannot be a resultant, R. Hence:

$$R_x = 0 \quad \text{and} \quad R_y = 0$$

consequently, $\Sigma F_x = 0$ and $\Sigma F_y = 0$.

Therefore, for equilibrium it is:

$$\Sigma F_x = 0 \quad \text{and} \quad \Sigma F_y = 0$$

This means that if a system of concurrent forces is to be in a state of static equilibrium, then the algebraic sum of the forces in both the 'x' and 'y' directions must sum to zero.

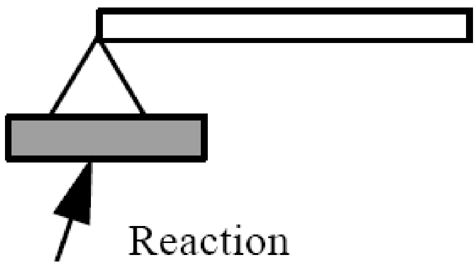
1.8 Free body diagrams

A free body diagram (FBD) is a sketched outline shape of the body which shows all forces (known and unknown), acting on the body. It is necessary in the solution of problems in mechanics (in statics), to be able to draw free body diagrams and understand their meaning.

1.9 Types of supports and their reactions

The supports of a structure supply the necessary active forces to create equilibrium by opposing the applied forces (ie loads). However, there are various types of supports and each of these is capable of supplying particular reactive forces (ie reactions). Two types of supports are considered in the following:

- Where the reaction is always normal (ie perpendicular), to the supporting surface, ie a smooth contact surface.
- A roller support, where the reaction is always at an angle to the supporting surface.



Example of pin or hinge support

1.10 The three force principle

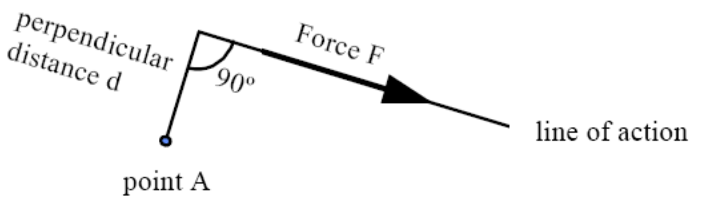
The three force principle is used where a body or structure in equilibrium is subjected to the action of three non-parallel forces. The three forces can be combined to form a three force body and consequently, determine the unknown forces necessary for static equilibrium.

1.11 Moment and torque

The moment of a force about a point is defined as the product of its magnitude (ie force) and the perpendicular distance from that point to the line of action of the force.

Therefore, moment of a force, M, at a perpendicular distance, d, about a point, A, is:

$M_A = F \times d$



Moment of a force

Working out units:

Moment = F x d

= [Newton] x [metre]

= [Nm]

In building and construction, it is more common to use kNm, where 1 kNm = 1000 Nm.

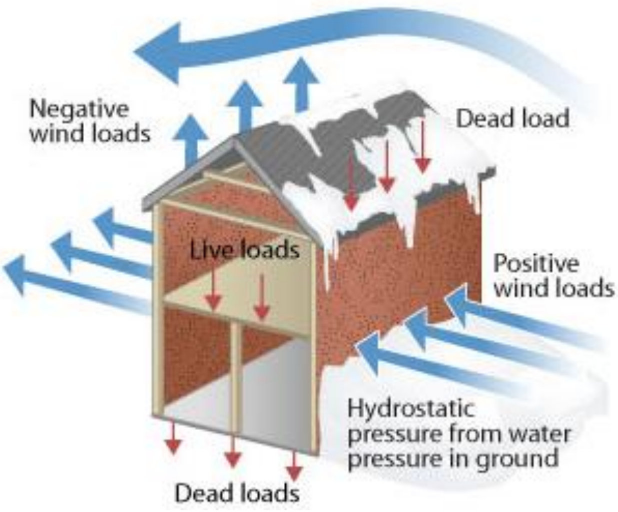
An important point to note is the sign convention used when making references to moments. It is commonly accepted that:

- clockwise rotation is defined as positive
- anti-clockwise or counter-clockwise rotation is defined as negative.

1.12 Addition of moments

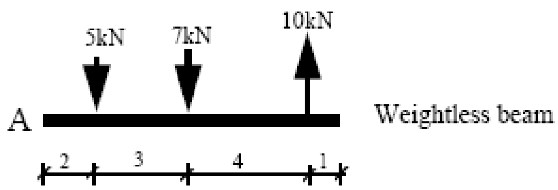
When a system of forces act on a body, there will be a resultant moment about a specified point of all the moments (resulting from each force) combined. The resultant moment is the 'algebraic sum' of the individual moments.

It is important to note that 'algebraic sum' implies that the positive (+) and negative (-) rotations about a point for each force must be taken into account when adding moments.



An overview of the many different forces acting on a building

For example, determine the resultant moment about the point A for the following force system:



Force system

Taking moments about point A:

M_5 = Fd = 5 kN x 2 m = 10 kNm, clockwise (ie positive)

M_7 = Fd = 7 kN x 5 m = 35 kNm, clockwise (ie positive)

M_{10} = Fd = -10 kN x 9 m = -90 kNm, anti-clockwise (ie negative)

Taking into account all moments, the resultant moment:

□M = $M_5 + M_7 + M_{10}$

= 10 + 35 + (-90)

= -45 kNm (negative, indicating anti-clockwise)

1.13 Equilibrium of moments

For a body (or structure) to be in equilibrium, there must be no motion of the structure, hence the forces as well, as the moments must be balanced. This means:

- Sum of clockwise moments = Sum of anti-clockwise moments
- Sum of clockwise moments + Sum of anti-clockwise moments = 0

That is, in equilibrium, the sum of moments is $\Sigma M = 0$.

1.14 Torque

The term 'torque' is very similar to that of 'moments' and uses the same sign conventions and SI units. Torque normally applies to mechanical components, for example, gears and shafts which require a period of continuous rotation in order to function. The equation for torque is:

Torque (T) = Force (F) x perpendicular distance (d)

For mechanical problems, the perpendicular distance is very often the radius giving us:

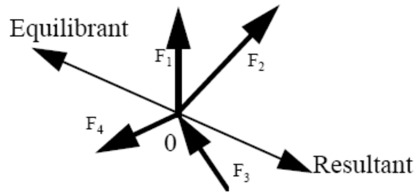
Torque (T) = Force (F) x radius (r)

1.15 Equivalent force moment systems

When looking at equilibrium of concurrent coplanar forces, it was shown that for a concurrent force system to be in equilibrium, the following needs to be satisfied at all times. ($\Sigma Fx = 0$ and $\Sigma Fy = 0$)

The resultant, R, which replaces the system or the equilibrant (the force which brings the system to equilibrium), was determined either graphically or mathematically using $\Sigma Fx = 0$ and $\Sigma Fy = 0$.

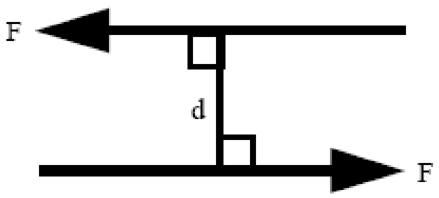
The position of the resultant or equilibrant was already known, since the lines of action of all forces in a concurrent force system must pass through one common point, that is:



Equivalent force moment systems

1.15.1 Couples

A couple is a system of two parallel forces, equal in magnitude but opposite in sense (and direction).



Couples

Forces are:

- parallel, ie parallel lines of action separated by perpendicular distance, d
- opposite in sense
- equal magnitude of forces, F.

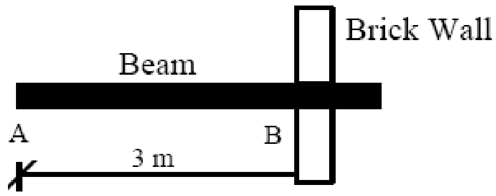
The only effect of a couple is to produce a rotation (or moment) in a clockwise or anti-clockwise direction, since the resultant force of the two forces constituting the couple is zero, 0.

1.15.2 Moment of a couple

The moment produced by a couple is equal to the sum of the moments of both couple forces, taken about any arbitrary reference point in space. It can be shown that the moment value of a couple is equivalent to the product of one of the forces by the perpendicular distance between the forces, irrespective of the arbitrary reference point chosen.

1.16 Equivalent force and couple system

Consider a beam, which is built into a brick wall (as shown below), having a length of AB equal to 3 metres:

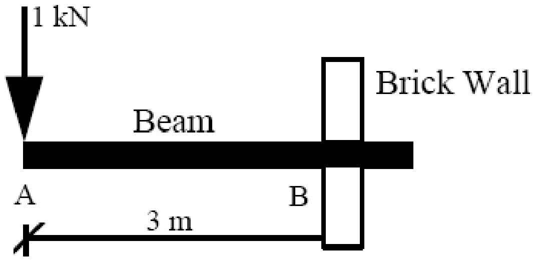


Beam built into a brick wall

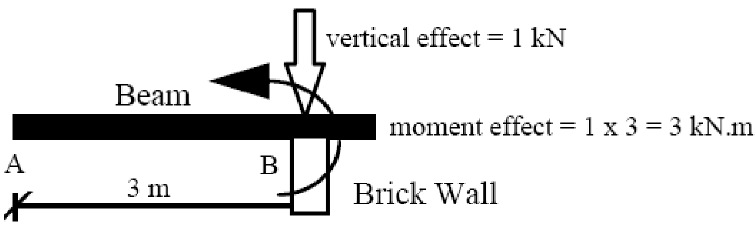
If a person was to stand at the end of the beam (at A), causing a downward force of 1 kN, what effect would the person have on the brick wall?

It would therefore be reasonable to assume that the beam at the wall would be subjected to:

- a vertical effect (due to the vertical downward force)
- a turning effect (due to the moment created by the force at the wall).



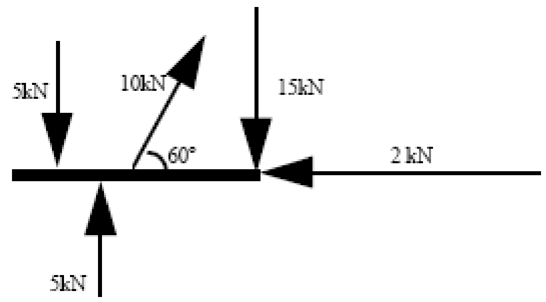
Vertical effect



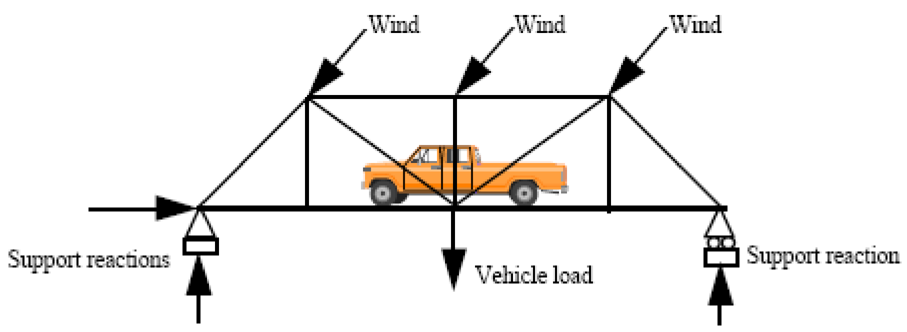
Turning effect

1.17 Equilibrium of non-concurrent coplanar forces

A non-concurrent force system is one in which the lines of action of all the forces in the system do not pass through the one common point.



Example 1



Example 2

In examples 1 and 2, the lines of action of all the forces do not pass through one common point.

1.18 Equilibrium of non-concurrent force systems

Many structures in our world are made up of non-concurrent force systems. In reality, almost all structures are designed so that they are in equilibrium, ie static equilibrium – a state of no motion in any direction.

It is evident that in order for a system of forces to be in equilibrium, the resultant force (ie Resultant), must be equal to zero.

That is, the algebraic sum of all forces in the (x) direction must sum to zero (0), ie $\Sigma F_x = 0$ and the algebraic sum of all forces in the (y) direction must sum to zero (0), ie $\Sigma F_y = 0$.

However, in the previous section, 'Couples', it was shown that when a body has forces acting on it, whose lines of action do not pass through the one common point, the question of the position of the resultant (or equilibrant), needed to be addressed and the concept of moment was introduced.

It was also shown that the structure (ie body) would tend to rotate. Therefore, in a non-concurrent force system, the forces acting on the structure may create a turning moment and therefore, a further condition of equilibrium needs to be introduced.

That is, the sum of the moments about any point of the structure must sum to zero:

- Sum of clockwise moments = Sum of anti-clockwise moments
- Sum of clockwise moments + Sum of anti-clockwise moments = 0

$\Sigma M = 0$

Hence, for a non-concurrent force system to be in equilibrium, the following three equations of statics must be obeyed at all times. ($\Sigma F_x = 0$, $\Sigma F_y = 0$, $\Sigma M = 0$)

2. Supports and reaction of supports of structures

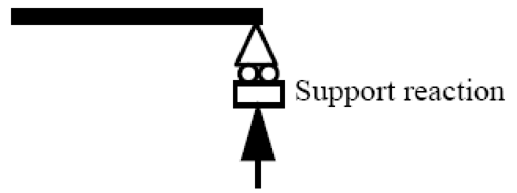
In this section we will be looking at the supports and reaction of supports of structures.

Structures have loads (ie forces) imposed on them in many ways. The forces are transmitted through the fabric of the structure onto the supports of the structure. The supports then supply the necessary active forces (ie reactions) to create equilibrium, by opposing the applied forces (ie loads).

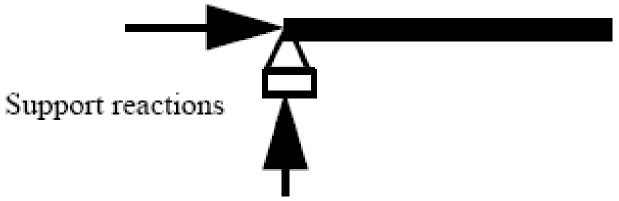
There are various types of supports and each type is capable of supplying particular reactive forces (ie reactions).

The section, Types of supports and their reactions, two types of supports and their reactions are introduced.

Both of these supports may be used to support a structure (eg a bridge or a beam).

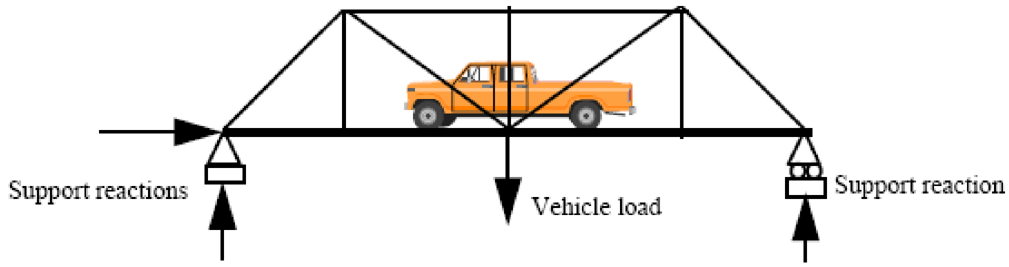


Roller support

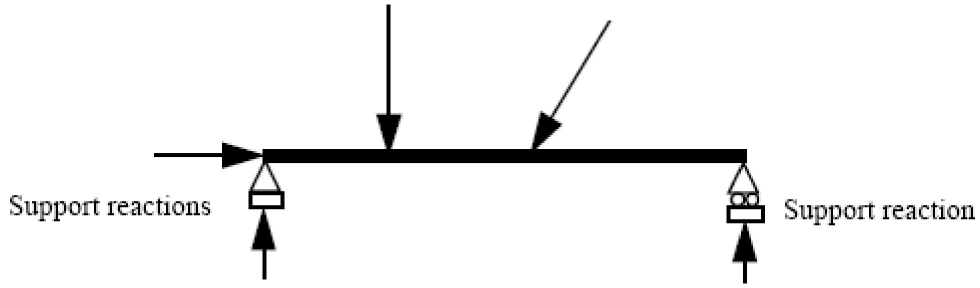


Pin or hinge support

Both of these supports may be used to support a structure, for example:



Support reactions for a bridge



Support reactions for a beam

Beams consist of a uniform constant cross-section, and are usually solid (sometimes hollow), long and straight.

It is common for beams to be constructed of reinforced concrete, timber, fabricated steel, rolled structural steel and sometimes, composite materials (eg steel and timber). Beams are commonly used in domestic and commercial applications.

Because of the manner in which beams are supported, they are referred to as:

- simply supported beam
- overhanging beam
- cantilever beam

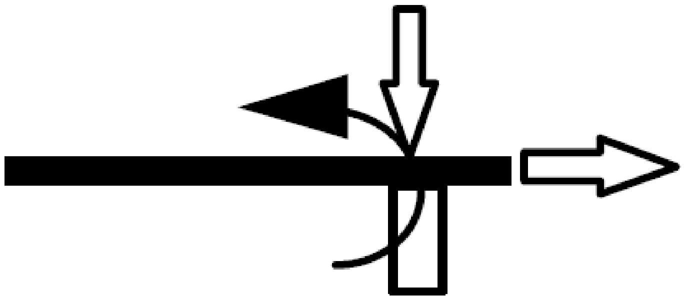
Simply supported beam

Overhanging beam

Cantilever beam

A cantilever beam is free at one end and rigidly fixed or built-in at the other end. The fixed or built-in end can supply three reactions, namely:

- a vertical reaction
- a horizontal reaction
- a moment reaction.

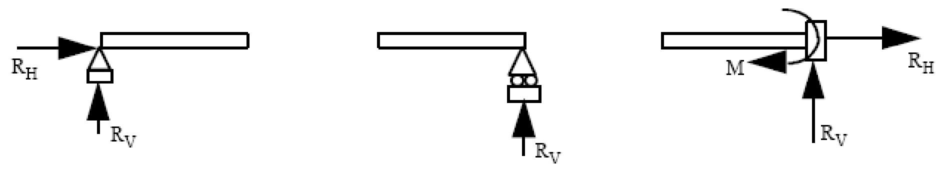


Three reactions

2.1 Summary of support reactions

It is normal to assume that the unknown reactions (to be determined), are positive, ie as for mathematics and the moment rotation is clockwise.

If the answer is negative to any one of the reactions calculated, then the sense and/or rotation will be opposite to that assumed.



Support reactions

It should be noted that some textbooks assume the unknown moment at the wall to be anti-clockwise, as in most cases, this will be the correct rotation sense of the moment reaction.

2.2 Determining the reactions

For equilibrium purposes, we have already established that the three equations of statics must be satisfied.

That is ($\Sigma F_x = 0$, $\Sigma F_y = 0$ and $\Sigma M = 0$).

In mathematics, it is a well known fact that you can only solve for as many unknowns as you have equations. Because we have three equations of statics, then we can only solve for three unknown reactions.

More specifically, in the case of a structure being supported as in the previous example, the structure is said to be determinate, ie all the unknown reactions can be determined using the three equations of statics.

In this Learner Resource, we are only concerned with determinate type supports of structures.

2.4 Determining reactions at the supports

The three equations of statics ($\Sigma F_x = 0$, $\Sigma F_y = 0$ and $\Sigma M = 0$) are used to determine the values of the unknown reactions at the support and checked to ensure that they are correct.

2.5 Steps to solving problems

Problem solving is a process (sequence of steps) that requires the application of skills and knowledge to discover, analyze and develop a solution for a particular problem or achieve a goal.

3. Roof trusses - pin jointed structures

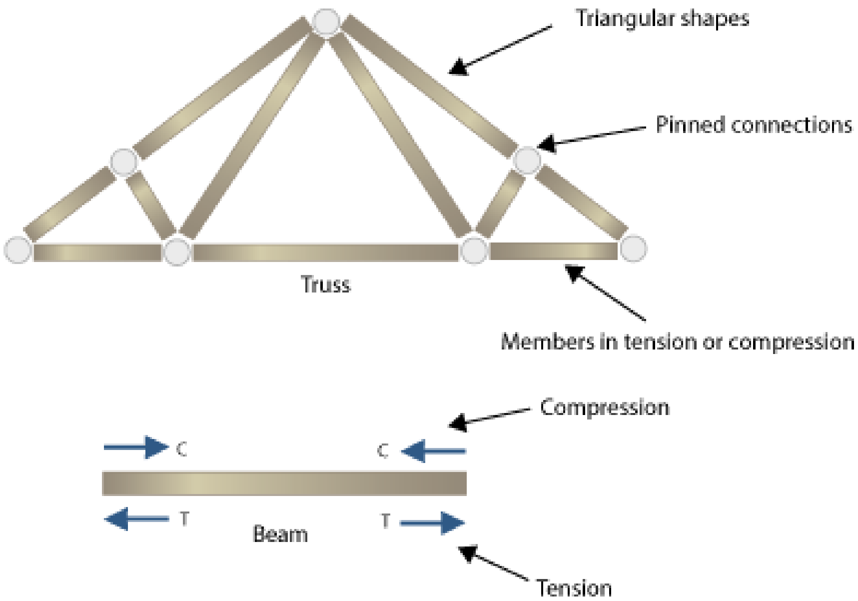
In this section we will be looking at the performance of roof trusses and pin jointed structures.

In practice, trusses are usually constructed using metal or timber materials. A truss is a framework of bars (ie straight slender members), the ends of the members being connected by various means. It is usual to connect the ends of the members by welding or bolting via a common plate, (ie a gusset plate), or by a single bolt passing through the end of each member commonly referred to as a pin.

Pin joint

In many instances, a truss is in effect a very large beam, but of course, it is far lighter than its solid equivalent, eg Sydney Harbour Bridge.

Also, trusses are commonly used to support roofs both in domestic and industrial applications.



Comparison of truss and beam

3.1 Roller support

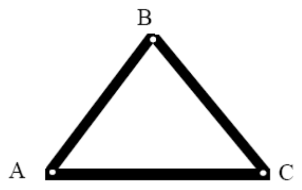
Sometimes, a roller type support is used for supporting one end of the truss for trusses spanning long distances. This allows the structure to move both for expansion and contraction of the members to accommodate applied loads and temperature effects.

3.2 Assumptions

Ultimately, for design purposes, the size of each member in the truss will need to be determined. It therefore becomes necessary to calculate the force in each member when the truss is subjected to its given loading and the following assumptions are adopted.

- The force in each member (or bar) is considered to act axially (ie along the centre-line of the member).
- All loads are only applied at the joints.
- Each joint is considered to be a smooth pin joint (and any friction is not considered).
- The centre line of each member of a given joint, all meet at one point and therefore, the joint acts as a concurrent force system.

The connection of the members (or bars) at a pin is known as the joint and the joints around the truss are normally labelled as joint A, B, C, etc.



Connection of members

A truss is drawn as a line diagram where each line represents the centreline (axis) of each member (ie plane truss – implying that all members lie in a single plane).

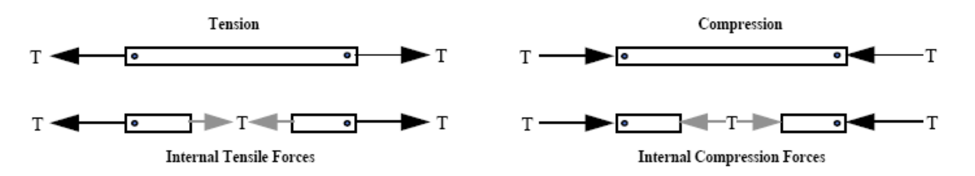
The weight of each member is not considered in any calculations as the magnitude of the applied loads on the truss makes the weight of members insignificant.

3.3 Member forces

Because each member in a truss acts as a two-force member and the force in each member is an axial force, then a member can either elongate (ie become longer than its original length), or shorten (ie become shorter than its original length).

If a member elongates, the member is termed to be a tensile force, T (ie pulling away from a joint).

If a member shortens, the member is termed to be a compressive force, C (ie pushing on a joint).



Tension and compression

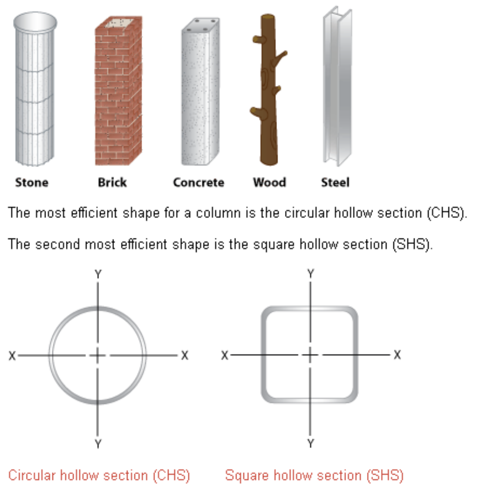
It therefore becomes important to distinguish which members in a truss are subjected to a tensile or compressive force as the design (ie final size), of the member will be different. For example, compressive members are normally larger in size than tensile ones, due to the buckling effect of compression members.

It is usual to assume that all unknown members are tensile (ie pulling away from the joint). If the answer is positive, then the assumption is correct and if the answer is negative, then the member is in compression.

4. Performance of columns

In this section we will be looking at the performance of columns.

Columns are vertical support members subjected to compressive loads. They are also referred to as pillars, posts, stanchions and struts.



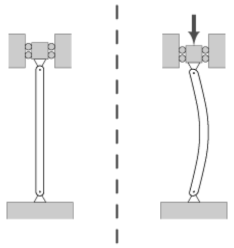
Columns

There are generally two types of compression members:

- Columns are generally relatively heavily loaded vertical members supporting beams, floors, roofs etc.
- Struts are generally lighter loaded compression members in trusses and frames.

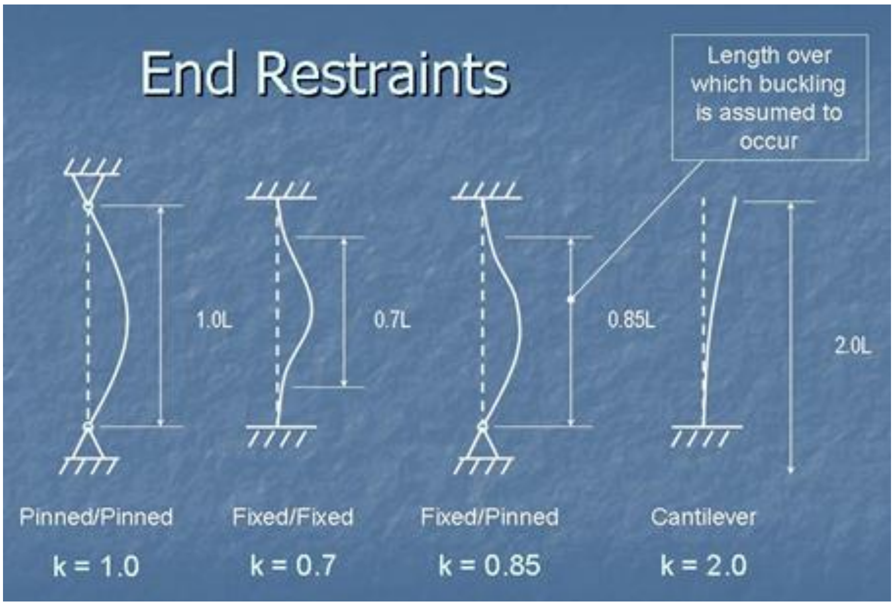
Both columns and struts are predominantly subjected to axial forces and are either stocky, slender or a combination of both:

- A stocky member (short column) failure will occur by compression of the material.
- A slender member (long column) which has a higher height to width ratio will fail by buckling. The longer the column, the more likely it will fail by buckling.



Buckling

- A member which displays both characteristics in combination is known as an intermediate column.



End restraints

4.1 Types of stress

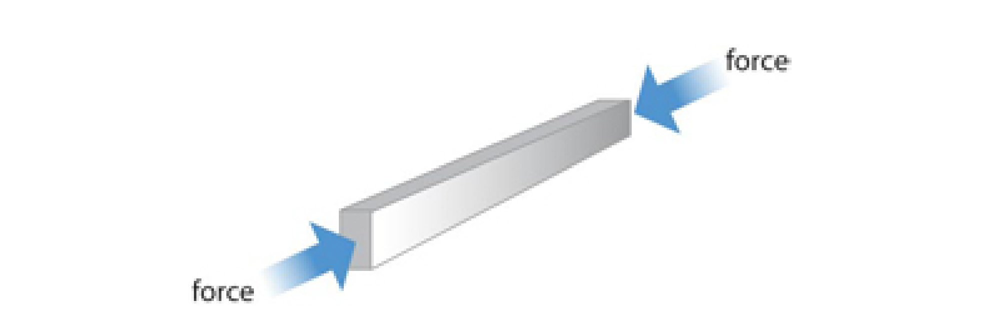
All materials when subjected to applied loads are required to be able to carry the applied loads without failure.

Consideration must be given as to how, or in what manner, the material may fail and therefore, design against such failures occurring.

The following shows forces pulling against each other (stretching the material).

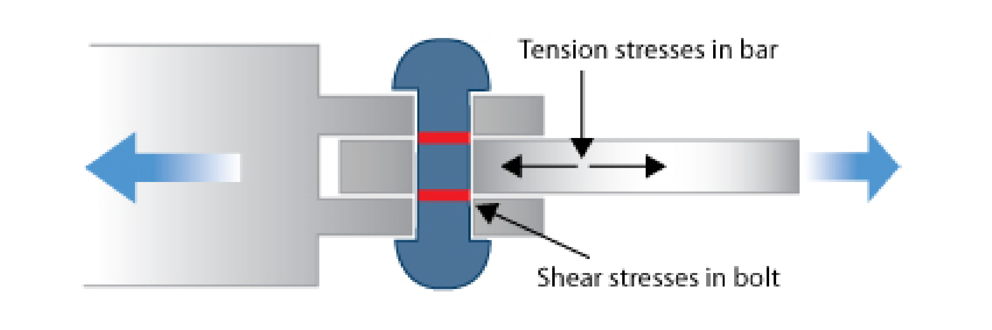
Tensile

The following shows the forces pushing against each other (compressing).

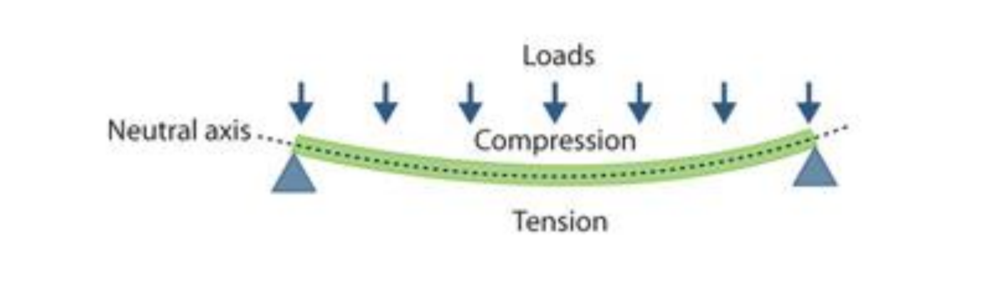


Compressive

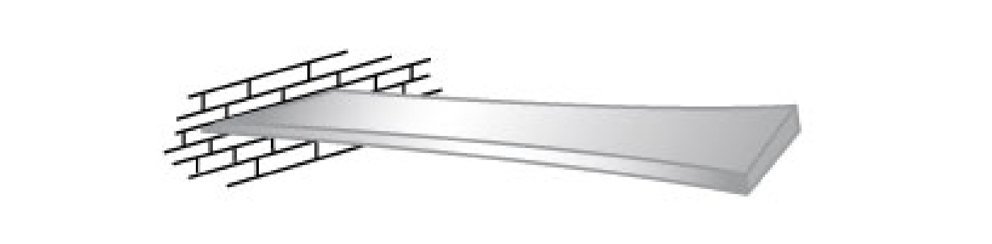
The following shows tension forces in the joint causing a vertical (downward) stress.



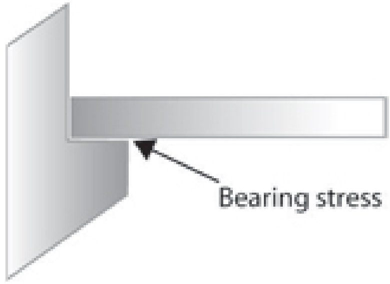
Shear



Bending

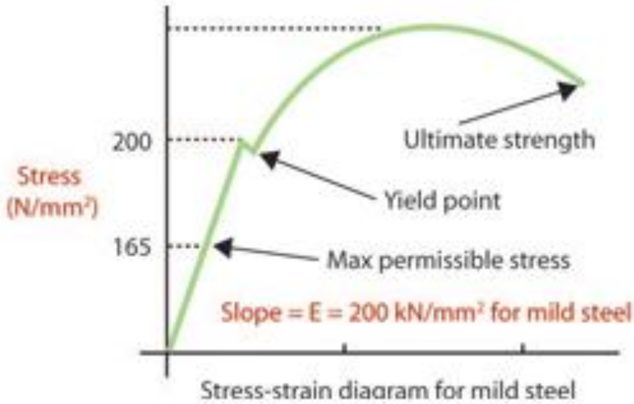


Torsional



Bearing

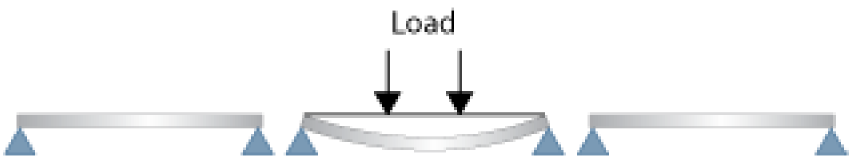
The following shows yield stress which is the amount of stress that will cause failure of a material (yield point).



Yield

4.1.1 Tensile strength

Almost all solid materials have some degree of elasticity. A material is said to behave elastically if it deforms under loading and then returns to its original shape when the load is removed.



Deforming under load

A load can be applied to a module in different ways. Therefore it becomes necessary to distinguish between the tensile, compressive and shear strengths of a material under load.

A typical requirement in design is the tensile strength of a material – this is commonly referred to as the ultimate tensile strength (UTS) and is defined as the ratio of the maximum tensile force applied before fracture divided by the initial cross-sectional area.

$$\text{UTS} = \frac{\text{Maximum tensile force}}{\text{Initial cross-sectional area}}$$

4.1.2 Units

Units are normally:

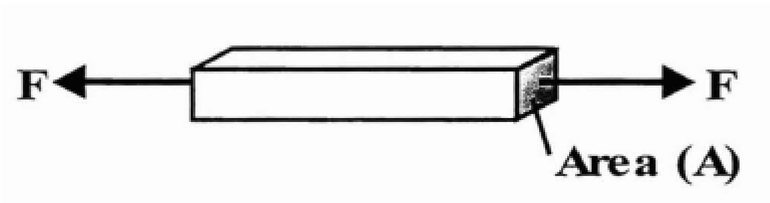
force = [Newtons]

Area = [mm^2]

Hence, UTS = [N/mm^2]

4.2 Direct axial stress in tension

Consider a force (F) applied in the manner shown in the following to a solid bar of uniform cross-sectional area (A):



Direct axial stress in tension

Direct stress is defined as the total axial load divided by the cross-sectional area (A).

$$\text{Direct stress} \quad (\sigma) \quad = \quad \frac{\text{axial load (F)}}{\text{cross-sectional area (A)}}$$

$$\sigma = F/A$$

4.2.1 Units of stress

The SI unit of stress is the Pascal (Pa)

One Pascal is equal to one N/m^2 (ie [Pa] = [N/m^2])

Hence, [MPa] = [N/mm^2]

4.3 Factor of safety

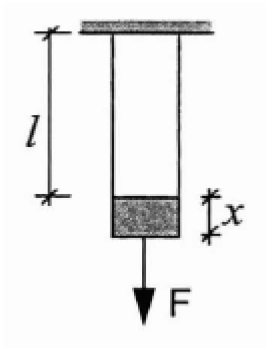
By definition:

$$\text{Factor of safety} = \frac{\text{ultimate tensile stress}}{\text{working stress (or allowable stress)}}$$

In design, the working stress is referred to as the allowable stress.

4.4 Axial strain in tension

Consider a solid bar in tension as shown.



Axial strain in tension

Where:

l = original length

x = change in length (due to load F)

$$\text{axial strain (e)} = \frac{\text{change in length (x)}}{\text{original length (l)}}$$

$$e = x/l$$

Since both (x) and (1) have the same units (ie mm), then strain is dimensionless or usually expressed as the change in length (mm) per original length (m) (ie mm per m length).

4.5 Hooke's Law

Hooke's Law states that strain (e) is directly proportional to stress (σ), producing:

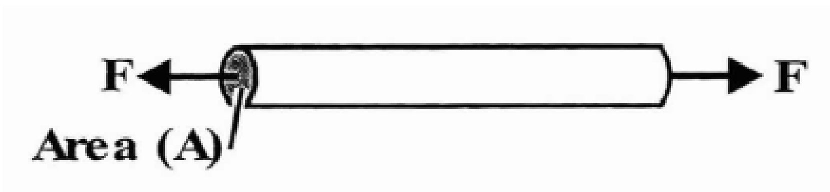
$$\text{Modulus of Elasticity (E)} = \frac{\text{stress } (\sigma)}{\text{strain (e)}}$$

$$E = \sigma / e$$

To explain Hooke's Law, it is necessary to understand the terms of stress (σ) and strain (e) and the behaviour of materials subjected to an axial load in tension by using experimental methods.

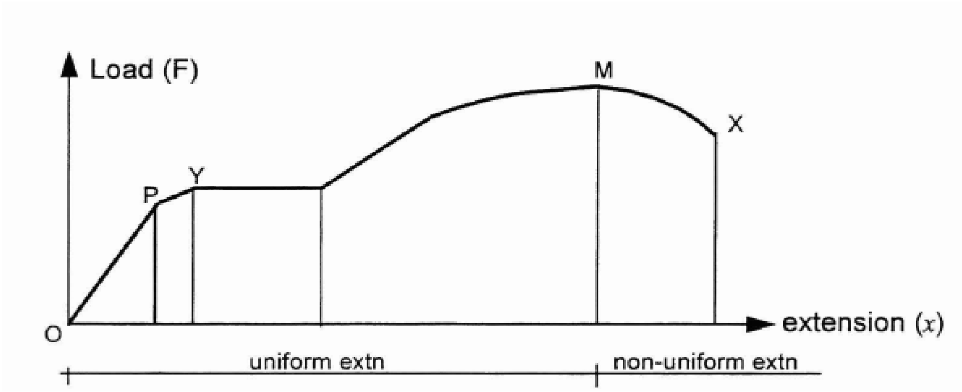
One of the most important tests to perform on a material is the tension (or compression) test, since the strength of a material depends on its ability to carry a load without permanent deformation or failure. Because this property is inherent in the material itself, it can only be determined by experiment. Such tests have been standardised and are recognised worldwide.

Consider a solid bar subjected to an axial load in tension.



Axial load in tension

As the load (F) is increased from zero to ultimate destruction of the specimen (ie fracture), a graph of load (F) versus extension (x) can be plotted as shown.



Black mild steel in tension

Over the range OP the material obeys Hooke's Law. P represents 'the limit of proportionality', beyond P the material no longer obeys Hooke's Law. If the material is loaded beyond P and then unloaded, a permanent extension remains called 'the permanent set'.

If the extension or compression in a member due to a load disappears on removal of the load, then the material is said to be 'elastic'. Most metals are elastic over a limited range of stress known as the 'elastic range'. Elastic materials, with some exceptions, obey Hooke's Law, which states that:

'the strain is directly proportional to the applied stress.'

At Y, the material stretches without further increase in load, Y is termed the' yield point' and the corresponding stress the 'yield stress'. Beyond Y, the steel is said to be 'plastic'.

M represents the maximum load, which the test piece can carry. At this point, the extension is no longer along the length of the specimen but is localised at one portion. The specimen begins to neck down. Local extension continues with a decrease of load until fracture occurs at point X.

The previous graphic shows load versus extension it is in fact a scaled down version of stress versus strain graph, since the cross-sectional area (A) and original length (1) of the bar under load are constant, that is (stress (σ) = F/A and strain = x/l).

4.6 Modulus of Elasticity (or Young's Modulus)

Since Hooke's Law states that 'strain is directly proportional to the applied stress', then:

$$\frac{\text{stress } (\sigma)}{\text{strain } (e)} = \text{constant} = E$$

That is, $E = \sigma / e$

where E is the constant of proportionality known as the Modulus of Elasticity.

Since strain is a ratio of two lengths, the units of E are the same as those for stress. Values of E may be given in basic form, N/m^2 or more conveniently, when large numbers are involved in MPa.

5. Properties of plane figures

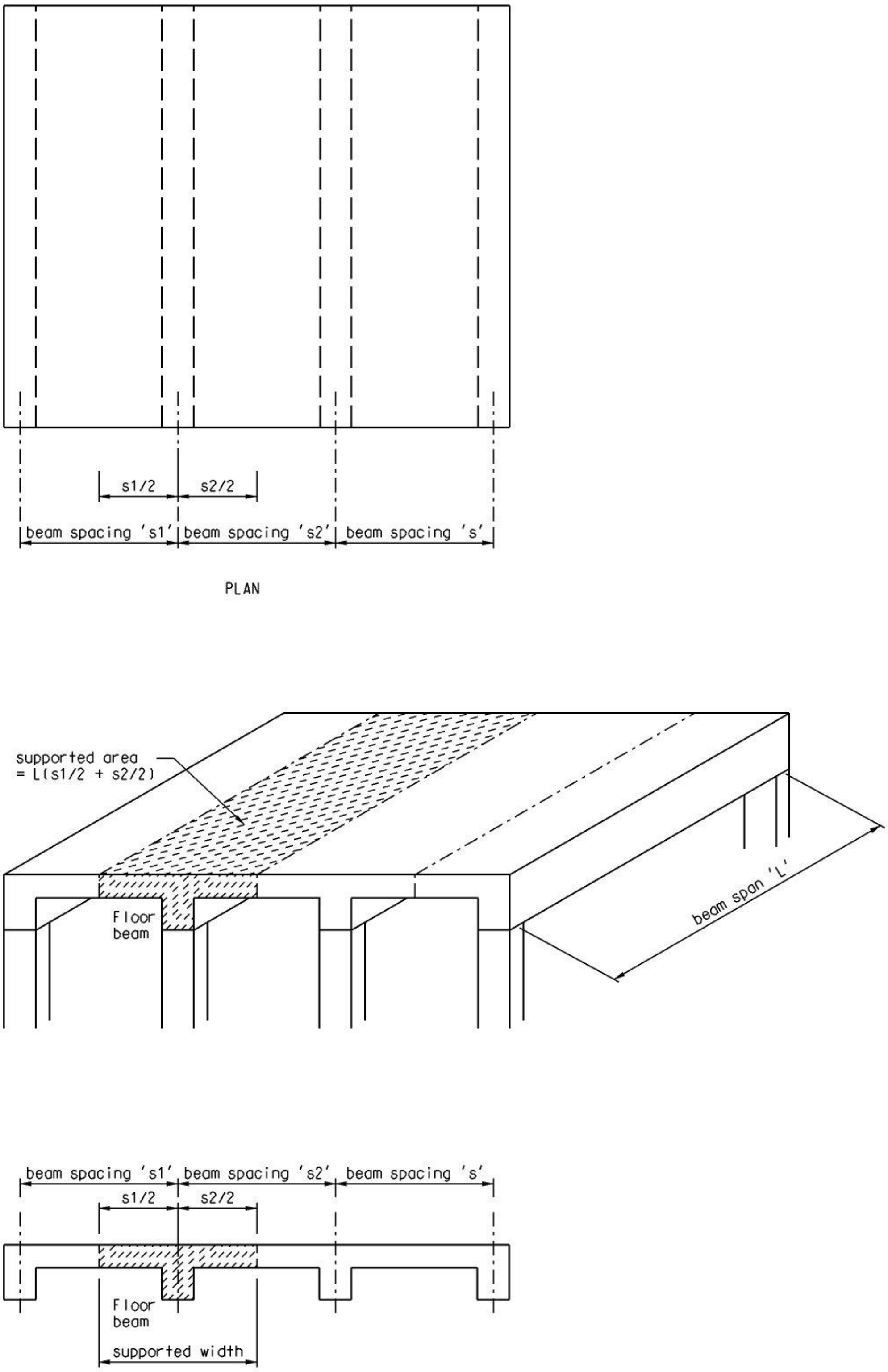
In this section we will be looking at the properties of plane figures.

The Oxford Dictionary defines a plane as being a flat surface on which a straight line joining any two points on it would wholly lie. In geometrical terms, this means that a plane is a levelled flat smooth surface without elevations or depressions. Plane figures are therefore figures which are closed and have levelled, flat surfaces.

The edges (boundaries) of plane figures can be straight, curved or a mixture of both. For example:

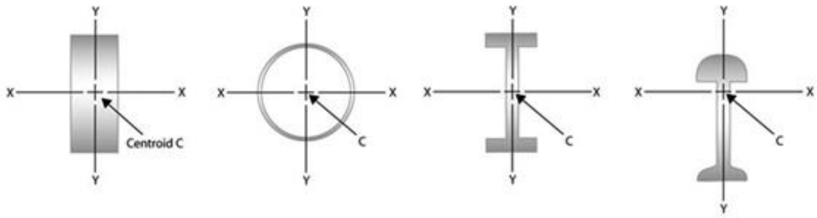
- square
- triangle
- circle
- rectangle
- parallelogram
- trapezium
- polygon
- rhombus.

The following is an example of a drawing showing a flat surface (floor), supported by beams.



Example of properties of plane figures

In mechanics, it is important to be able to design a structural member. In order to do so, it becomes necessary to be able to determine the geometric centre (or centroid), ie $\bar{x}$ and $\bar{y}$ of a particular area. Having located the centroid of a section, it is then possible to determine the moment of inertia (I) of the area in question.



Geometric centre

5.1 Centroid of plane areas

The centroid of an area is a geometrical concept and not a mass related concept.

The centroid of a plane area is a point which defines the 'geometric centre' of the area in question.

If the area is assumed to be of a material which is uniform and homogenous, the specific weight will be a constant throughout and this term will cancel out of the equation and therefore, is of no consequence.

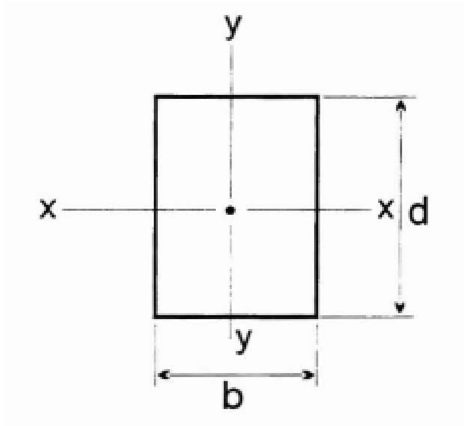
Most shapes can be sub-divided into basic shapes such as squares, rectangles, triangles and circles (and respective hollow areas). The centroids of these basic shapes are commonly known.

Centroids of composite shapes can be calculated by dividing the shape into basic sub-areas and applying the 'first moment of area' principle.

5.2 Moments of inertia of plane areas (I)

The moment of inertia (I) is often called the 'second moment of area'. Whereas in locating the centroid, the first moment of area implied sub-area multiplied by perpendicular distance, in the case of (I), the perpendicular distance is squared.

Again, the values of (I) of basic areas, have been determined for both the x and y axes. It is worthwhile noting that in each case of (I) for basic areas, the side that is not cubed is the side parallel to the axis under consideration.

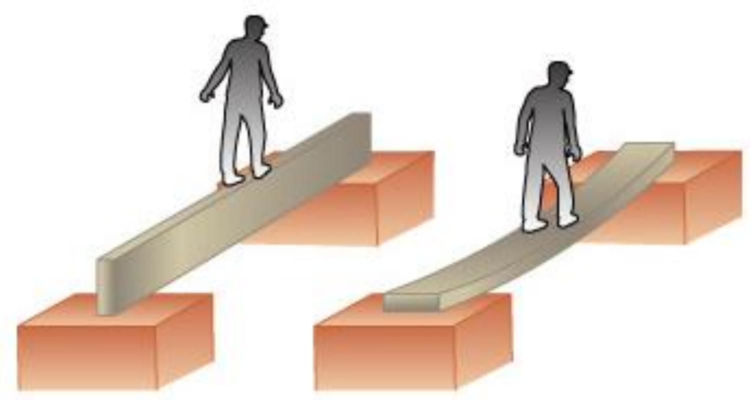


$$I_{xx} = \frac{bd^3}{12} \qquad I_{yy} = \frac{db^3}{12}$$

Moment of inertia

5.2.1 Second moment of area

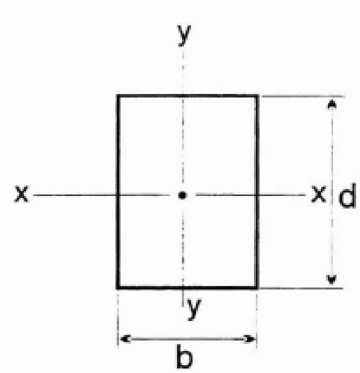
The second moment of area (I), of an area (A) with respect to any given axis is the product of the area (A), and the square of the perpendicular distance from the centre of area (A) to the axis' (about which the moment is considered).

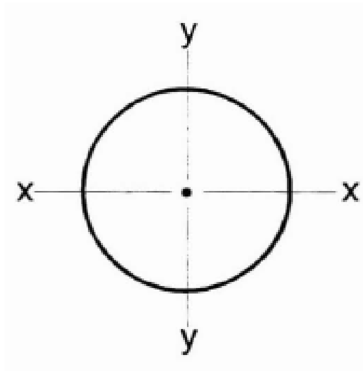


Second moment of area

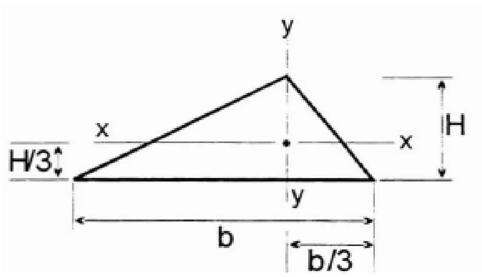
Using integration, the second moments of area of common sections about an axis through the 'centroid' or centre of area are derived.

Using integration, the following formulae are derived for standard shapes.





$$I_{xx} = \frac{bd^3}{12} \qquad I_{yy} = \frac{db^3}{12} \qquad I_{xx} = I_{yy} = \frac{\pi d^4}{64}$$



$$I_{xx} = \frac{bH^3}{36} \qquad I_{yy} = \frac{Hb^3}{36}$$

Standard shape examples

5.2.2 Units

If $I_{xx} = \frac{bd^3}{12}$ then if b and d are in (mm) as most dimensions of shapes are, then the unit of (I) is mm^4.

It is common to express (I) as a multiple of 10^6.

For example:

$$I_{xx} = 284 \times 10^6 \, mm^4$$

Many steel sections are fabricated as standard and are available from a number of suppliers. You should access the Internet to review some of the literature provided by the steel suppliers to obtain information about their products.

6. Bending stress

In this section we will be looking at bending stress.

Bending stress (σ_b) applies to sections that are being subjected to bending by externally applied loads. This normally occurs in beams, which are members that are slender and support loadings that are applied perpendicular to their longitudinal axis.

Bending stress is not uniform over the cross-section of a beam. When a beam is subjected to bending part of its cross-section, it will be subjected to compressive action and the other part subjected to tensile action.

For a beam cross-section to change from compressive to tensile stress over its depth, there is a point over the cross-section at which neither compression nor tension stress in bending occurs. This point is termed the neutral plane or neutral axis.

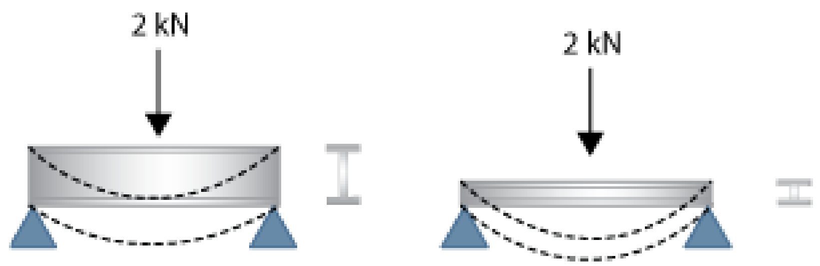
In fact, this neutral axis is the centroid of the cross-section of the beam.

7. Deflection by formulae

In this section we will be looking at deflection by formulae.

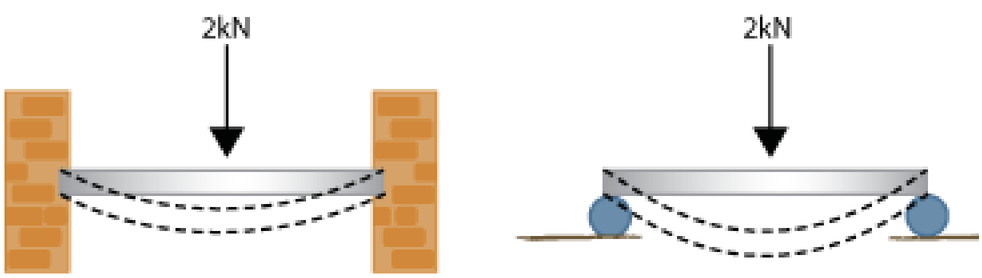
Deflection refers to the amount a beam bends. It is, therefore, important in the design of structural members, in particular beams, to ensure that deflections are not exceeded. The resulting damage could prove to be quite expensive to repair.

For example, a cracked plaster ceiling caused by excessive deflection of joists or excessive deflection of a lintel over a garage opening cracking the brickwork it is supporting above as a gable.



Deflection

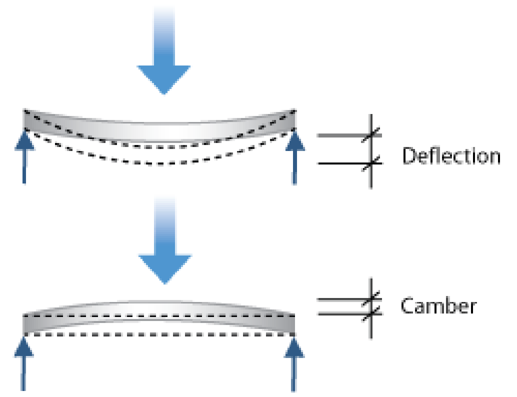
The restraints on the supports of a structure directly affects its deflection. For example, the beam below has two types of supports thereby affecting its deflection shape and the amount of deflection.



Example 1

7.1 Camber

The deflection of a beam can be positive or negative, ie concave or convex, ie above or below the beam.



Camber

Whilst equations can be devised to determine deflections by a number of means, standard equations can be used to determine deflections for various loaded beams. These equations are in the form:

Y is a function of a constant times $\dfrac{FL^3}{EI}$

where:

Y = deflection [mm]

F = applied load [N]

L = beam dimension [mm]

E = modulus of elasticity [N/mm^2]

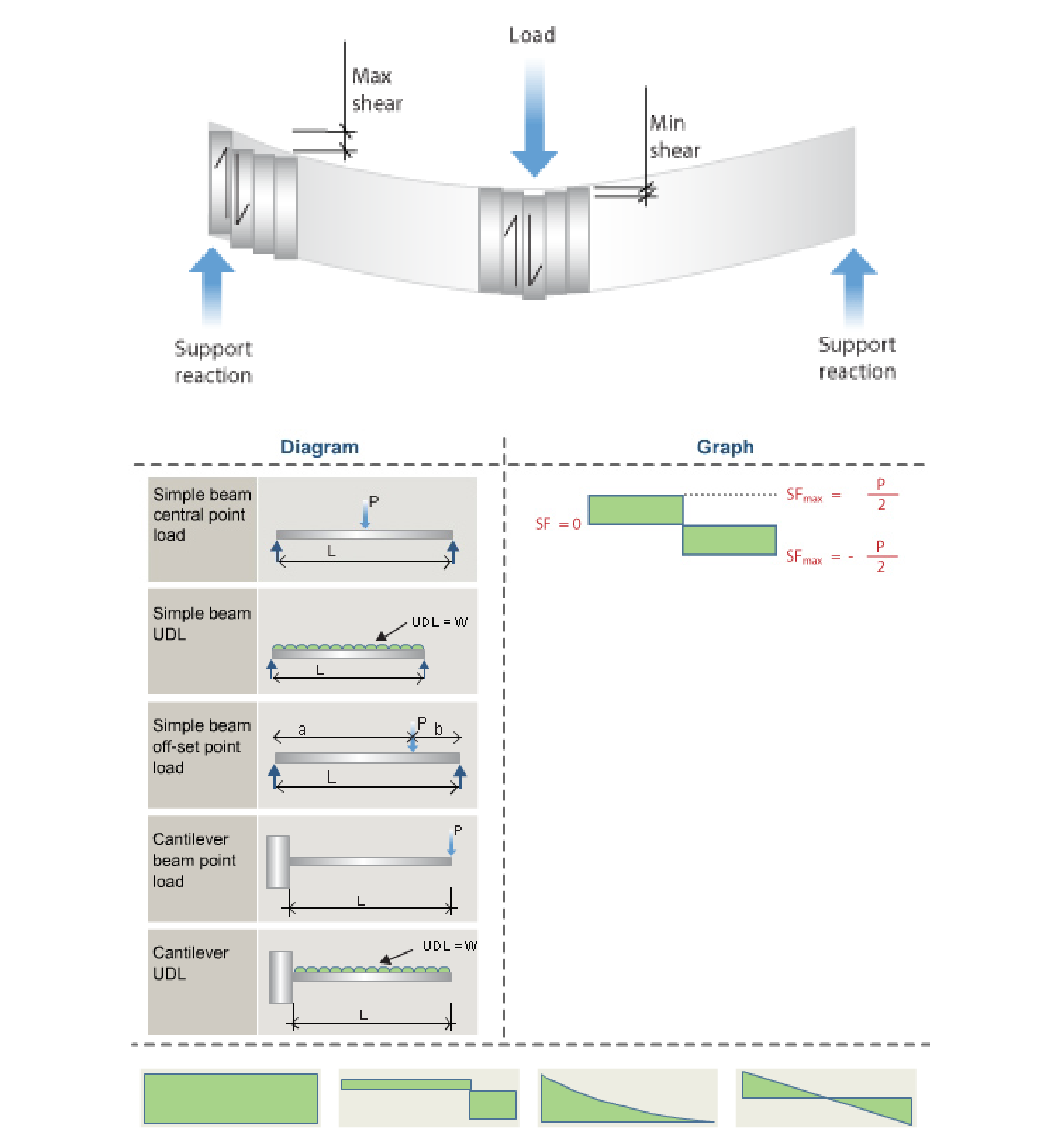
I = second moment of area or moment of inertia [mm^4]

8. Shear force

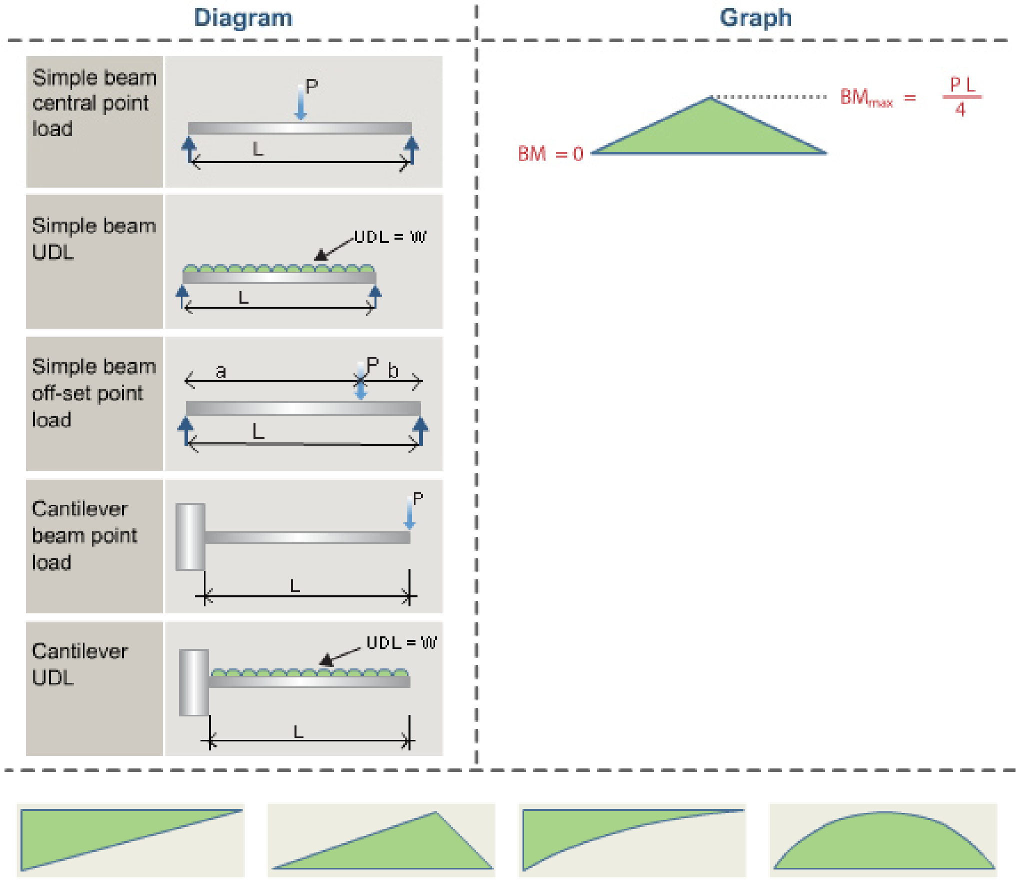
In this section we will be looking at shear force.

Shear force diagrams (SFD) and bending moment diagrams (BMD) are tools used as part of structural analysis in the structural design process. The diagrams show the determination of the value of shear force and bending moment at a given point of a particular element. You can use these diagrams to determine the:

- type and size of a member of a given material
- deflection using either the moment area method or the conjugate beam method.



Shear force diagrams

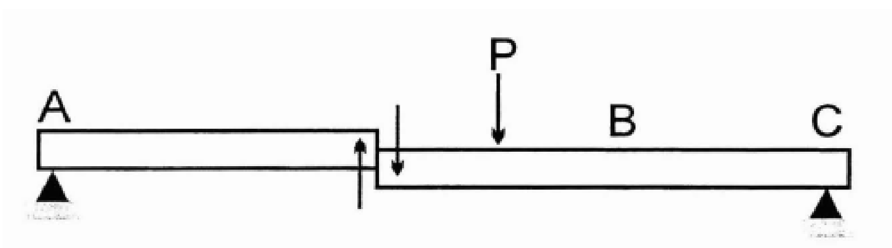


Bending moment diagrams

When a beam is loaded, it is expected that the beam (ie structural member) will carry the loads safely.

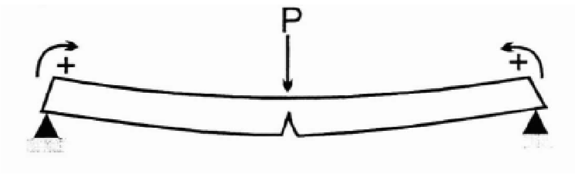
A loaded beam may fail in two main ways:

1. The beam, if not designed properly, will fail by shearing. The excessive load will shear the beam across its cross-section (as shown in the following graphic).



Shear force

2. The beam, if not designed properly, will fail by bending an excessive amount (as shown in the following graphic).



Excessive bending

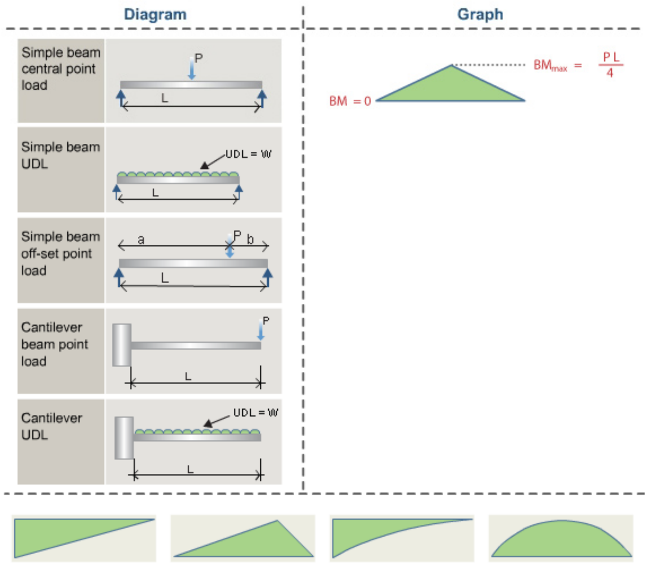
It should be noted that:

- failure of a beam by shearing or excessive bending does not occur at the same time
- by plotting the shear force diagram (SFD) and bending moment diagram (BMD), their respective values (ie maximum or otherwise), are used in other forms of calculations, such as stress calculations in order to determine if the proposed beam will be within the allowable limits under a particular loading condition.

8.1 Bending moment

Bending moment is a factor which measures the bending effect at a particular point of a loaded beam.

The value of bending moment at a particular point on the beam is determined by taking moments either to the left hand side or right hand side of the point in question.



Bending moment

The normal sign convention for positive bending moment is convex downwards.

Positive bending

Therefore, adopt the convention of left hand side of beam about the point at which the bending moment value is to be determined.

PART 2

Introduction

This Learner Resource, 'CPCCBC4010B, Part 2', addresses Elements 2 to 7 of the unit of competency *CPCCBC4010B Apply structural principles to residential low rise constructions*.

To obtain competency in CPCCBC4010B you must complete both the CPCCBC4010B, Part 1 and Part 2 Learner Resource for this unit of competency.

1. Planning

The structural principles of a residential low rise structure are subject to the conditions set out in the Building Code of Australia (BCA), Volume Two, Classes 1 and 10 buildings (Housing provisions).

1.1 Structural principles

The BCA objective is to protect people, property and to primarily safeguard people within and outside the building structure (Reference: BCA, Part 2.1, 02.1).

Whilst the BCA state the functional aspect of the building (Reference: BCA, F.2.1), the performance requirement states that the building structure must have structural stability and resistance to actions (Reference: BCA, P.2.1, (a), (b), (c) and (d)).

1.2 Structural performance

The structural performance of the building is determined by the effect of the sectional properties of the various materials.

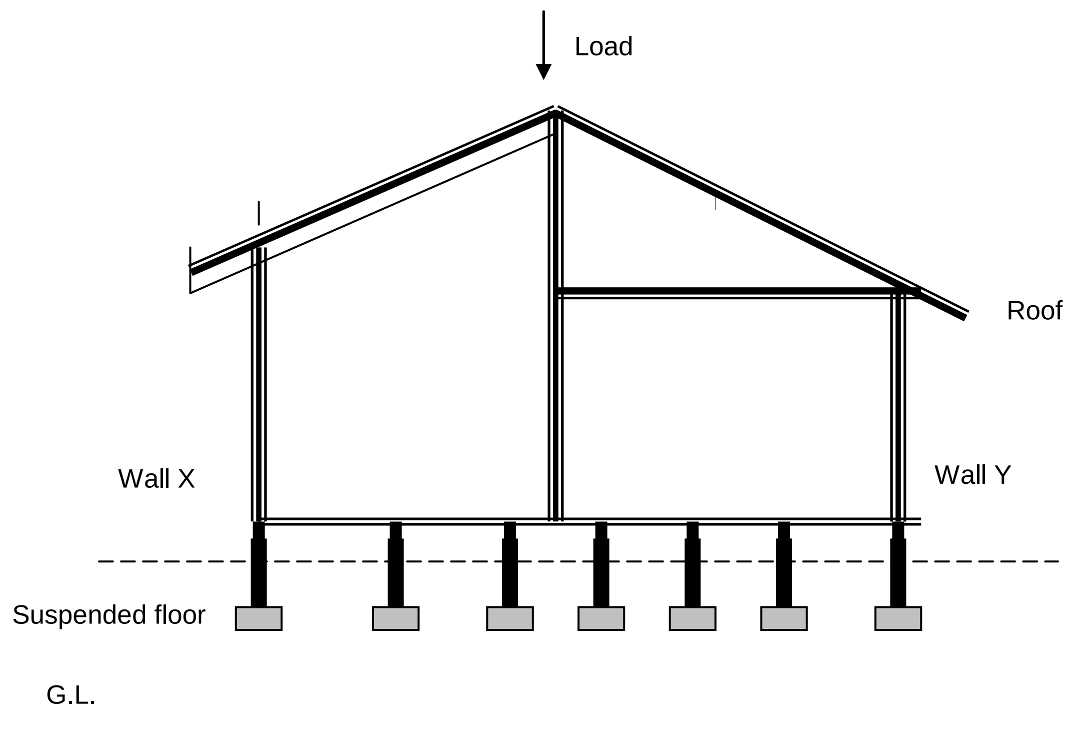
In BCA, Volume Two, Classes 1 and 10 buildings, the material suitability and evidence of sustainability is tabled in Part 1.2 – 1.21 and 1.2.2.

As material sectional properties form an integral element in the design and construction process, it is a BCA requirement that calculation methods comply with Australian Building Codes Board (ABCB) protocols or certification from a professional engineer in structural, civil, mechanical or design disciplines.

1.2.1 Structural performance characteristics

The structural performance of all components are subject to the NCC. The structural resistance of materials and forms of construction are tabled in NCC, Part 3.11.6. Design and known loads are listed in:

- AS/ANZ 1170.1 Structural design actions – permanent, imposed and other actions
- Table BCA 3.11.3a in the BCA.



Typical cross-section of a house

1.3 Demolition of existing structures

The demolition of an existing structure is subject to the:

- BCA
- Code of Practice for Demolition (WorkSafe Australia)
- Occupational Health and Safety Act 2004 (Vic) with amendment.

The above Code of Practice and reference to the Occupational Health and Safety Act applies to Victoria.

A demolition contractor is subject to public liability insurance and demolition proposals/plans submitted to the local municipal council must include:

- the method of demolition
- equipment to be used
- storage facilities for all plant and materials
- demolition plans.

As demolition procedures vary from the basic to complex, there are many instances of foundation instability, adjoining or attached buildings and site conditions which require shoring, temporary scaffolding and propping – these require engineering computations.

In any structural element of construction, whether the building is being constructed or demolished, the project documentation should be checked for engineering design and specification, and if underpinning, rock anchors or shoring is required, then additional documentation is required for specialised demolition practice.

1.4 Analyse and plan for the structural integrity of buildings

Within the building industry, there are relevant industry professionals such as architects, engineers, building designers, draftspersons, quantity surveyors and licensed land surveyors with whom you will consult during a construction project.

The roles of these industry personnel include providing advice on the design process and verifying that the structural integrity of Classes 1 and 10 buildings has been met. The following sections outline the contribution these types of personnel make to the design process.

1.4.1 Architects

An architect provides the conceptual elements of the proposed building to the client. After consultation, an agreement of a contract between the owner and the architect is made. The architect can then prepare the working drawings and specifications based on a series of preliminary meetings, proposed sketches and finally, the complete drawings in confirmation with all codes, standards, regulations and local authority approvals.

As a function of the architect's role in designing and building, there is also the provision for supervision by the architect. Because the building is constructed in stages, the architect may wish to inspect each stage and verify that the critical aspects of design and structure have been complied with.

At all stages of the preparation of working drawings, the criteria of adherence to structural principles are paramount on residential low rise constructions.

Following the design process, the five common stages of construction are:

- foundations/footings also referred to as base structure
- wall and roof framing
- lock-up
- fitout
- completion.

In addition to the actual structure, compliance is required with town planning (under certain circumstances), environmental laws and sustainability factors.

Depending on the cost and complexity of the building, the architect may choose to engage a project manager, who will effectively become the full-time superintendent of the project. The project manager may be paid by the owner, and retained by the architect, or takes this position as a senior member of the contractors' staff.

Architects receive their information and professional assistance through their membership and affiliation with the Royal Australian Institute of Architects (RAIA).

1.4.2 Building designers

A building designer has the professional skills and knowledge to design and draft residential, industrial and commercial buildings. Many offices also provide construction supervision.

In Victoria, to operate their own business they have to be qualified to the Advanced Diploma of Technology, have a minimum of three years practical experience and sit a Building Practitioners Board assessment.

Today, building designers carry out (in Victoria), a significant amount of the building design and documentation of a wide range of projects.

Umbrella organisations, such as the Building Designers Association of Victoria (BDAV), offer support and provide guidance to this industry.

1.4.3 Draftspersons

A draftsperson has the professional skills and knowledge to design and draft residential, industrial and commercial buildings.

The role of the draftsperson can vary, but primarily their duties involve the following:

- assisting in planning and design
- assisting in gathering information to produce concept drawings
- assisting in the initial building design
- working in an office administration position.

Whether the building is being erected or demolished, the architectural draftsperson has a role to perform.

Umbrella organisations such as the Building Designers Association of Victoria (BDAV), and support from the Housing Industry Association (HIA), provide support and guidance to members.

Whilst it is the role of the architect and/or the building designer to prepare the drawings, the completeness of the plans and documentation will be ultimately scrutinised by a building surveyor.

1.4.4 Engineers

As all parties have some input into the structural integrity of the structure, the engineer is a specialist party who provides initial input, guidance and ongoing assessment of the structure. Engineers can be categorised as either civil or structural, or by specialist areas such as landscaping, acoustics, electrical and electronics. There are also many other building areas that require expert engineering involvement.

A structural engineer provides the design to structural members of the building; to account for all live and dead loads and produces a set of structural work drawings, which are certified as legal documents and form part of the complete set of working drawings. Typical structural elements could include:

- slabs design and placement of reinforcement
- strength of concrete
- type of position of all piers, piles and floor structure
- all structural beams, posts and columns.

The engineer bases all computations on standards, codes, regulations and compliance with the BCA.

Brick veneer home under construction

1.4.5 Quantity surveyors

In the larger residential low rise constructions, the quantity surveyor calculates the total cost and amount of all materials and labour used in construction by preparing a bill of quantities. Generally in residential projects this responsibility is undertaken by the estimator working for the builder when preparing their tender.

The calculation of quantities can vary from an estimation and a costing schedule to a bill of quantities. The bill of quantities is classified as a legal document – it therefore becomes an essential component in the overall contract documentation.

The working drawings are the essential tool upon which all construction is based, and from these, all materials and costs are estimated by the builder and each of the relevant trades and/or suppliers.

1.4.6 Licensed land surveyors

The licensed land surveyor is a registered industry professional who verifies that the proposed building is placed on land of clear title and that all easement, boundaries and dimensions are according to the title documents. As properties are marked with survey pegs showing the boundaries, the pegs are classified as a legal document and penalties exist for illegally removing or altering the site boundaries.

The structural integrity of all building components relies on being straight, level and plumb, although other miscellaneous shapes are used. It is the land surveyor who can check the alignment of components during construction using sophisticated instrumentation including laser levels, theodolites and dumpy levels.

It is the responsibility of the principal contractor to ensure that all project documentation is collected and analysed, and that plans and specifications are complete and meet the necessary legal requirements.

This is the architects'/building designers' responsibility in obtaining a building permit. The builder has to verify that the detail on the drawings are correct, and that the drawings and the specifications agree with each other. He takes the responsibility of checking all the drawings, details, levels and dimensions before he starts work on the site. Many a job doesn't fit on the site!

The information in the specification takes precedence over the working drawings should there be a discrepancy between both.

Activity 1 – Consultation regarding structural integrity

The final sketch plans are being prepared for the owner, after having the layout of the new house accepted by them. However, he has just asked for an additional window to be put in the family room.

The new window required is to be 3.600 metres wide, located at ground level in a two-storey house. How does the draftsperson go about altering their documentation to date to allow for this new window?

Check your findings with the correct answer in the back of this Learner Resource under ‘Learning activity answers’.

* Retain this learning activity as part of your personal portfolio of studies.

1.5 Project documentation

A building permit is required to commence any building. In some cases, a planning permit is also required. When a planning permit is necessary, it must be obtained before the building permit.

Project documentation is essential to ensure conformance with BCA requirements, including bushfire, high winds, and other environmental factors.

Request for site information from various municipal, governmental and private organisations can be a lengthy process. Documentation requests forms and fees apply in most cases.

Today, the information to locate all services is easily obtained from 'Dial before you Dig' phone 1100.

The following documentation is required in order to obtain a building permit from the local municipal officer:

- three copies of the title
- three copies of the plan
- three copies of the soil report
- three copies of the specifications for the proposed structure
- three copies of the computations (if applicable) to the structure
- necessary fees
- application form
- flooding levels (required by certain councils)
- survey and reduced levels of site
- statistical data relevant to BCA requirement (eg area of permeable land on allotment after construction).

If a private building surveyor is used, then four copies of each of the above documents are required and it is this office that handles variations and the running of the project. At the completion of the project, the private building surveyor provides a copy of the project file to the municipal building surveyor.

The plan room

Activity 2 – Collecting and analysing project documents

The private Building Surveyor is looking over the plans for a new 300 m^2 brick veneer home with a structural concrete slab floor.

What documentation must be provided within the file for the design of the concrete slab?

Check your findings with the correct answer in the back of this Learner Resource under ‘Learning activity answers’.

* Retain this learning activity as part of your personal portfolio of studies.

1.6 Emerging building technologies

New materials are continually being developed, and these new materials are being combined with other new or existing materials to form new structural components of a building that are very strong, cost effective and lightweight.

Where can we see these on a building site?

- Lightweight pre-cast concrete panels that are structural members of a building.
- Curtain walls built from steel through to plastic, and supporting an external finish that could be glass or stone.
- Whole buildings being constructed using pre-fabricated building components.
- The use, again, of Adobe earth walls, and mud bricks or even straw bale houses.
- Steel trusses being replaced with metal space frames.
- Fully glazed rolled roofs, supported by minimal structure.
- The new additives being added to concrete to provide strong industry resistant floors.
- Manufactured wood products that are now available for almost any use within a building project.
- The glues and resins that when used in laminated products are developed for all types of uses.

Activity 3 – Assess new building technologies

Conventionally, we have built the wall separating two units (both Class 1), with a double brick wall, generally with a parapet wall between the two occupancies.

Briefly describe an alternative method of construction for this type of 'party wall'.

Check your findings with the correct answer in the back of this Learner Resource under 'Learning activity answers'.
* Retain this learning activity as part of your personal portfolio of studies

1.7 Site investigation

Pre-commencement site inspection must be conducted to confirm analysis of the building site.

The following site features should be established before any building is undertaken:

- Survey pegs

  A land surveyor should carry out a ‘check survey’ known as a ‘re-establishment survey’ to establish that the pegs are in the correct position.

- Natural flora

  Site visit should establish the vegetation and mature trees on the site as certain local councils require permits to clear certain vegetation.

- Slope

  A land survey should establish natural ground level to design within the height limits of regulations and standards.

  It must establish levels over the site and their resultant contour lines.

- Drainage

  Stormwater legal point of discharge and system layout can be established by requesting information from the relevant service authority.

- Sewage

  Legal point of entry sewer system can be established by requesting information from the relevant service authority.

- Water

  All water pipes servicing a domestic building site can be established by requesting information from the relevant service authority.

  Care must be taken to determine a short or a long tapping ie, is the water main on your side of the street or across the road. If conduits have not been placed under the road in a new sub-division, then this can be costly. Look for the location of the fire hydrant to locate the water main.

- Adjoining properties

  Records – written, sketched and photographed of all adjoining properties should be taken before any work commences on the site and made into a ‘site conditions report’.

- Power

  Electricity, gas and other power systems servicing the site should be established by requesting information from the relevant service authority.

  Again, ensure that you know what side of the road that they are on – for overhead power, or services, clearances above ground levels are most important.

- Access

  Location of crossovers and other public land should be identified to establish requirements for protection of same. Note that a secure site is an OHS requirement and may require the use of items such as safety barriers.

- Street frontage

  This report should also contain similar information detailed above for the crossover to the site, the nature strip and footpath and the kerb.

  In this case, should there be any damage to any of these the site supervisor should meet with the municipal engineer to record all the faults that exist. This is because at the end of the project, when the builder applies for his 'asset protection security deposit' back – it is most likely that council would ask them to restore this damage, assuming that it happened during the construction works. The report relieves the builder of that responsibility, although they are liable for any further damage that they carried out.

- Classification

  Site classification (General) (BCA, Volume One, Part 3.2.4).

  A building is classified as to its use (ie the use to which the structure is put – eg office/warehouse/car park) (BCA Column 2, Part A3, Page 2501, Section H).

There are different names for specific parts of a structure, but basically any structure can be divided into two parts and these are:

- Substructure – below natural ground level.
- Superstructure – above natural ground line.

Walls below natural ground line are referred to as the substructure.

1.8 Building loads

The following types of building loads need to be considered when planning for building a low rise residential building:

- Dead: The weight of the structure and all parts of fixed components.
- Live: Occupants, furniture, equipment, rain, snow, moveable.
- Lateral (wind): Wind pressure from all directions as regards to size, height of structure of the building.
- Other (seismic): Earth movement, shock, horizontal loads on foundation walls by earth and water pressure.

The following table provides an overview of the structural components of a low rise residential building, including the purpose of the structural components and the materials that are commonly used for such components.

Structural component	Uses and materials
Walls	Walls carry all loads of the structure to the footing, in addition to this, it also keeps out the elements. Wall materials include masonry, timber, metal, concrete, manufactured materials and/or stone.
Columns	Materials used for columns include masonry, timber, metal, concrete, manufactured materials and/or stone.
Loads	Loads are carried by columns/beams/girders, ie they constitute the structural frame.
Trusses	Made of timber, metal and/or concrete.
Rigid frames	Rigid frames are a form of arch in timber, metal and concrete.
Arches, domes and vaults	Masonry, stone, timber, metal and concrete.
Twisted steel-wire strand cables	Used to support large spans, eg roofs and cantilever projections of roofs.

Site works

1.8.1 Pressure and capacity

The following types of bearing pressure and capacity need to be considered as part of the structural requirements for the building:

- Bearing pressure: Intensity between footing base and foundation bed.
- Allowable bearing pressure: Recommended design pressure that will safely insure against excessive settlement, rupture or fracture of foundation materials.
- Bearing capacity: Ability of foundation material to safely support imposed loads.
- Ultimate bearing capacity (UBC): Governed by the safety factor (normally 2 to 3 of 10). UBC = S.F. 4/2 = Safety factor ABC.

1.8.2 Foundations

Bedding planes (horizontal/inclined), may be of rock (may be exposed or buried), or soil (loose or compacted), and can be found to be hundreds of feet deep.

Variation of rock classes can occur a short distance apart and/or at different depths. Site investigation is very important, as rock, with a high bearing capacity, may be under layered with a low bearing capacity sand, eg peat and clay soils which may cause heaving/slipping during wetting and drying.

Exploration

Soil investigation should be undertaken to determine:

- underlying materials
- ground water depth
- settlement.

Exploration and testing of foundation soil includes analysis of soil grain size and type:

- Rock: 12 mm+ (average sieve size) maximum sieve size
- Gravel: 2 mm – 1 mm (average sieve size)
- Sand: Granite/basalt etc (silicon dioxide and quartz)
- Silt: Floury (silicon dioxide)
- Clay: Hydrous alumina silica/quartz, eg iron oxide (flat flakes similar to mica)

There are various tests that can be conducted on soils:

- liquid limits
- plastic limits
- shear resistance
- compressibility
- elasticity
- consolidation
- solubility
- permeability.

Foundation soils

Key points for the investigation of foundation soils include the following:

- Inspect nearby buildings and pavements and check with local builders and authorities to evaluate soil conditions.
- Building authorities require soil tests and engineer-designed footings. Alternatively, the use of standard footing and slab designs for each classification of soil (stable, intermediate and unstable), is permitted. If there is doubt about soil classification, have a soil test carried out.
- Assess findings of inspections and tests in relation to climate and particular site conditions.

- Load carrying ability of soil is not critical for small buildings unless the soil is silty mud, wet sand or poorly compacted fill.
- Clay and other volume changing soils swell and shrink as moisture content of the soil varies.
- Volume changing soils under buildings or pavements dish down or dome up as moisture content of covered and uncovered soil varies.
- The depth and underground profile of volume changing soil may cause variations of movement on a single site.
- Distinct wet and dry seasons cause soils to dry out more and wet up quickly, resulting in sudden, extreme movements of volume changing soil.

Settlement

Settlement is the downward movement of the base of a structure. The effect upon the structure depends on its magnitude, its uniformity, length of time it takes place, and the nature of the structure itself.

The causes of settlement include:

- imposed weight – the weight of the building
- change in moisture content of the soil
- subsidence due to mining or similar operations
- general earth movement.

Cohesive soils

Cohesiveness is dependent on the bearing pressure, the compressibility of the soils and the depth, width and shape of the footing. In cohesive soils (which are highly compressible), reduction in volume takes place by the expulsion of pore water, and as permeability is low, consolidation takes place very slowly.

Non-cohesive soils

With non-cohesive soils such as sand and gravel, settlement is minor and keeps pace with construction loading.

Choice of foundation footings

The type of foundation adopted depends largely on the form of construction used and the structure should be designed to react to differential settlement in soils, such as clays and silt.

Causes of localised soil moisture variations include the following drying and wetting factors.

Drying factors:

- tree roots
- pavements
- sewerage connection
- bores and wells
- granular backfill
- well drained sites.

Wetting factors:

- lopping trees
- garden watering
- soakage trenches
- leaking pipes and taps
- impervious backfill
- poorly drained site.

Other factors that should be taken into account in foundation soil include:

- keeping trees with a high water demand well away from buildings in volume changing soil areas
- filling should be non-volume changing granular material, placed and mechanically compacted in layers – the maximum thickness of which depends upon the type of fill used
- designing in aggressive soil conditions requires expert advice
- siting conditions of shape, geography, land slip or subsidence must be considered in conjunction with the quality of the foundation soil.

Activity 4 – Site investigation

For typical residential construction sites, discuss all preliminary site investigation required to obtain a building permit. Use the CD Rom Build right Toolbox BCGBC4007A / or associated notes in this learner resource.

Use this information to ensure all investigation features are included.

Check your findings with the correct answer in the back of this Learner Resource under 'Learning activity answers'.
* Retain this learning activity as part of your personal portfolio of studies.

Activity 5 – Site investigation research

Describe, with the aid of sketches, how you would explain the following terms as they might apply to the site preparation of a building site. In preparing your sketches base your answers on a building site that is 18 metres wide x 40 metres in depth. The front boundary is at the level of the road, whereas the rear boundary is 2 metres higher.

1. Site scrape (applies generally to a flat site).

2. Name the two Australian Standards that cover site investigation issues.

3. Explain the meaning of 'bearing capacity' of soil.

4. Are footings and foundations the same thing? Explain your answer.

5. For 'made-up ground', where should the footings be founded?

6. What five topographical matters should be considered in a site investigation?

7. Explain the difference between an 'M' and 'MD' classification.

8. List two ways trees and shrubs affect the footings.

9. Explain the term ‘differential movement’ as it relates to the brick foundations of a wall.

10. What is meant by ‘reactive’ soil?

11. What is the minimum bearing pressure recommended in the building regulations?

12. Why are footings for soil classified as ‘E' deeper than those classified as ‘M’?

13. For a class ‘M’ site, what is the minimum cross fall of paving?

a) What type of drain would you use to divert surface water from around a house on a sloping site?

b) Where would this water be diverted to?

14. At what distance should trees be planted near a house?

15. Describe a bore log.

16. Describe the process a soil engineer would use to classify soil on a domestic building site.

Check your findings with the correct answer in the back of this Learner Resource under 'Learning activity answers'.

* Retain this learning activity as part of your portfolio of evidence.

2. Laying of footings

As with all other components in the construction of a building, the footings form the integral part of the substructure.

Footing is classified as the section of the structure, which transfers the load of the structure to the foundation or ground.

Foundation is classified as the ground/foundation beneath the footing, which carries the load of the building.

Depending on the type of foundation material, the footing type is selected by the building designer/architect and is subject to structural computations to determine its ability to take levels.

The commonly used footing types include:

- bored pier footings
- column or stump
- pier and beam
- concrete slab.

There are many other footing types but generally, they are variations of the pier and beam or flat slab.

Stump holes ready for inspection

2.1 Footings set out

Strip footings are required to brick veneer, cavity brick and solid brick construction.

As trenches need to be excavated and accurate building lines determined, the builder is required to position profiles or hurdles on which to string the line and show the outside face of brickwork and the outside line of the proposed concrete strip footing.

Base structure complete

Floor joists laid over bearers

2.2 Concrete slabs

Concrete slab construction can take many forms but the most commonly used types are:

- stiffened raft
- footing slabs
- waffle slab, pier and beam
- slab on ground.

Concrete after formwork stripped

Whilst there are many different methods of establishing a footing on-site, the most important feature is that the footing is designed and poured to have absolute structural integrity. Accepted industry principles dictate common practices and providing these practices conform to all standards, codes, regulations and manufacturer's specifications, the individual practices prevail.

All foundations are subject to geotechnical engineering approvals, compliance with AS 2870 Residential slabs and footings – construction and the NCC, Volume 1, Classes 1 and 10 buildings, Part 3.2.5.

As an initial commencement point, the foundation is classified by the AS 2870 as being Classes A, S, M, H or E. Classes A – P for filled sites are listed in Clause 2.4.6 and P sites are listed as SH soils, landslip and soils likely to be reactive.

Floor joists being loaded onto bearers

2.3 Footings and slab compliance

Footings are classified as being suitable for common soil conditions by the NCC Volume Two, Classes 1 and 10 buildings. Footings and slabs are governed by their size, shape and structural reinforcements.

As concrete is to be poured into the excavation, all parts of the excavation must be free of loose earth, debris, mud and tree roots.

The excavation soil cut and depth must comply with NCC, Part 3.1.1 and in the case of concrete slabs, all filling under slabs must conform with NCC 3.2.2.2 and AS 1289 Methods of testing soils for engineering purposes, method 6.3.3.

2.3.1 Concrete

As reinforced footings are the primary structural feature of the construction, the concrete has to be discharged from the truck in the required time of one and a half hours. If a suitable retarder has been used in the mix, the setting time will then be prolonged.

The concrete should be discharged into the form or trench and compacted by vibration. The durability and resistance to termite infestation will be significantly reduced by careful concrete practices.

Ancillary factors such as rain, wind and temperature also affect the quality and durability of the concrete and this should be determined by concrete supplier's documentation and working drawing specifications.

Concrete slabs should be cured for at least seven days and building materials or plant should not be stacked on concrete during this seven day period. (Reference: NCC, Volume Two, Classes 1 and 10 buildings Part 3.2.3)

Concrete can be tested for consistency and strength by use of the slump test and/or a compression test.

A slump test should be taken from every truckload of concrete delivered to the site – a slump of 100 mm is acceptable for most residential construction.

When concrete is mixed, it is from nominal 20 mm aggregate, Portland cement and potable water. The cement and the water, when mixed in the right proportions, causes a chemical reaction to occur and this reaction causes heat to be produced.

This heating process that causes the slab to dry out is called 'hydration'.

When ordering concrete, we request 25 MPa. This means that the concrete must achieve the strength of 25 MPa within 28 days.

2.3.2 Footings – damp coursing

Footings provide the structural base for the complete building and because the elements of the building in contact with the ground are subject to dampness, some protection is required.

Water can enter a building through an accumulation of surface water or as groundwater entering the building as rising damp.

The NCC, Part 2.2 'Damp and weatherproofing' describes the treatment of water within the functional statement reference.

With reference to Part F2.2.1 and the performance requirement in Part 2.2.1, note that the NCC describes dampness as being unhealthy, causing loss of amenity for building occupants and possible deterioration of building elements (Reference: NCC, Part 2.2.3).

2.3.3 Damp proofing

The damp proof course (DPC) is placed in the base structure to stop rising damp and the material must extend the full width of the masonry leaves.

General practice places the DPC 150 mm above the ground level and below the line of the timber bearer. See NCC, Volume Two, Figure 3.3.4.1. Refer to Part 3.3.4.4 in regard to the use of suitable materials. There are five alternative DPC types listed and referenced in Australian and New Zealand Standards (Reference: AS/NZ 2904 DPC and flashings).

DPC installation is noted on the designer's specification and unless an alternative solution is proposed, the parts of NCC 3.3.4.1 and 3.3.4.5 prevail for all penetrations through the slab.

Buildings prone to termite attack must be protected. There are a number of chemicals, manufactured hard barriers and organic types of termite prevention barriers.

Certain designated areas are prone to possible termite attack and this means that laws and NCC legislation will affect both the planning and building in areas designated to be at risk. The NCC clarifies the following methods of providing receptacle termite barriers and these include:

- Termite shielding – Sheet materials are placed in the formwork and slab to prevent the ingress of termites.
- Stainless steel mesh – Parts of the slab substructure can be reinforced by stainless steel mesh, including all reinforcing components.

For further information regarding damp coursing and termite barriers, refer to the following texts:

- Building your own home
- Building a house (see 'Footing Systems' section)
- Building Code of Australia, Volume Two.

Activity 6 - Check footing specifications

Choose a residential low rise construction plan and check the specification of the following:

1. Subfloor:
   - Stumps
   - How far does the stump go into the stump pad?
   - Depth of stump (Ds)
   - Pad size
   - Backfill
   - Bracing – when do stumps have to be braced?

2. Spacing of bearers

3. Damp proof course

4. Floor joists

5. Floor systems

6. Structural wall systems

7. Wall cladding

Check your findings with the correct answer in the back of this Learner Resource under 'Learning activity answers'.

* Retain this learning activity as part of your portfolio of evidence.

Activity 7 – Flooring systems

Answer the following questions.

Subfloor

1. List the material suitable for stumps and give reasons for your answers.

2. Define the following:

   a) Sole plates

   b) Single span

c) Continuous span

d) Span table

Bearers

1. What controls the spacing of bearers?

2. How are bearers joined?

3. How is the bearer fixed to the stumps?

4. Describe the placement of bearers to walls.

Floor joist

1. What controls the spacing of floor joists?

2. What controls the placement of floor joists to walls?

Flooring

1. List a number of materials suitable for floor systems.

2. Briefly explain and sketch an example of a fitted floor and a platform floor.

3. What materials are suitable for damp proof course?

Check your findings with the correct answer in the back of this Learner Resource under 'Learning activity answers'.

* Retain this learning activity as part of your portfolio of evidence.

Activity 8 – Subfloor layout

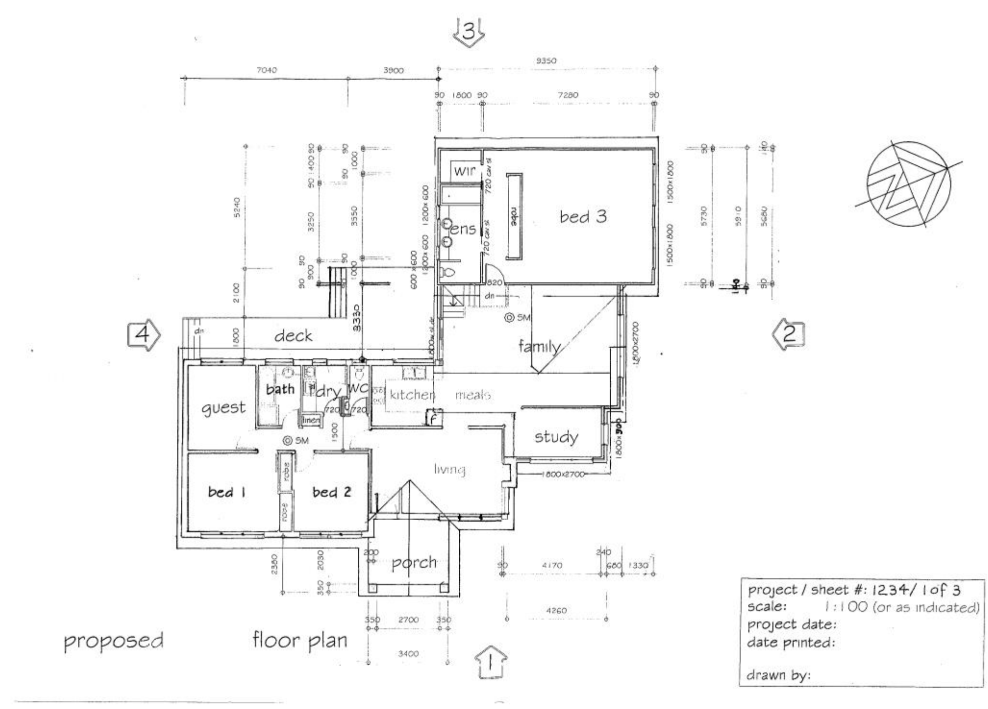
You are required to establish the subfloor layout drawing of a timber clad dwelling with the following specifications:

- All walls are load bearing
- Bearers are 100 x 75 f8 @ 1800 centres
- Floor joists are 100 x 50 f8 @ 450 centres
- Stumps are type 2 footing
- Soil classification is Class S

Draw the following:

- Stump layout
- Bearer layout
- Floor joist layout

Use the space on the following page to make notes about your drawings.



Establishing subfloor layout

To view detail on this plan, you should increase the screen view size on your computer.

Notes for Activity 8 – Subfloor layout:

Check your findings with the correct answer in the back of this Learner Resource under 'Learning activity answers'.

* Retain this learning activity as part of your portfolio of evidence.

Activity 9 – Specification requirements

1. Identify where you would find the specification requirements for the following (note the document and clause).

   a) Minimum strength of concrete for a footing:

   b) Thickness for a slab on ground:

   c) Depth below the edge rebate of a slab:

   d) Minimum REO cover in a strip footing:

e) Minimum REO cover in a slab on ground edge beam:

f) Minimum REO cover for fabric of slab panel:

2. Regarding reinforcement requirements:

a) What is meant by the term 3L 11TM (3F11TM)?

b) What is meant by the term SL 82?

Check your findings with the correct answer in the back of this Learner Resource under ‘Learning activity answers’.

* Retain this learning activity as part of your portfolio of evidence.

Activity 10 – Footing specifications

Identify where you would find the specification requirements for the following (note the document and clause).

1. Footing for a single storey brick veneer dwelling on a site with Class ‘M’ conditions:

    a) Minimum size of a strip footing:

    b) Minimum size slab edge beam:

2. Suspended floor systems for a brick veneer dwelling:

    a) Class ‘M’ footing size:

    b) Concrete stump size:

c) Type 2 concrete pad size:

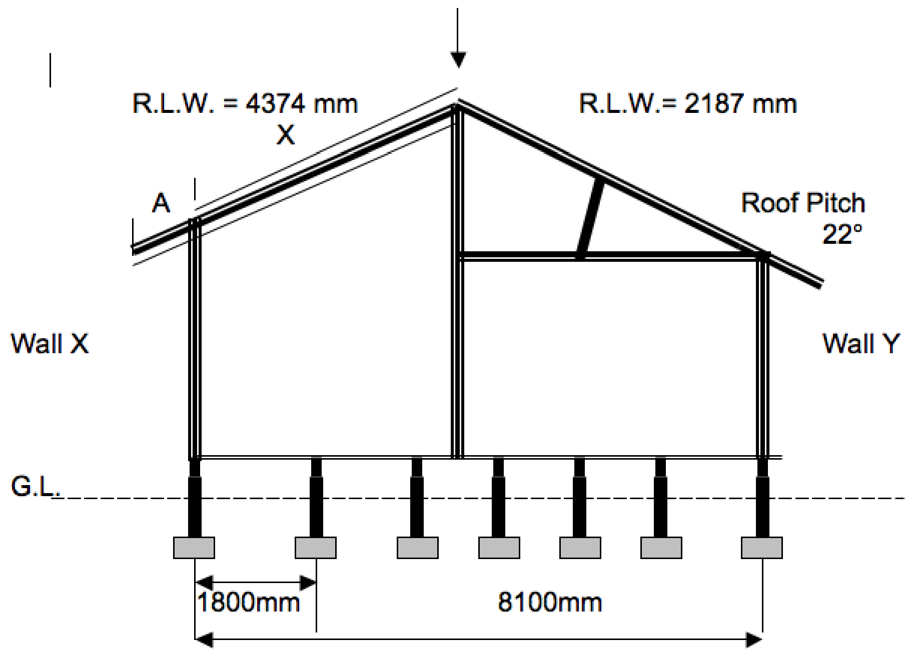
d) Height of the bearer above ground line for a platform floor:

Check your findings with the correct answer in the back of this Learner Resource under 'Learning activity answers'.

* Retain this learning activity as part of your portfolio of evidence.

Activity 11 - Suspended floor systems

If stumps are to be placed below 100 x 75 F8 bearers, which will be carrying a suspended floor system as shown below?



Carrying a suspended floor

You are required to find:

1. Size of F8 floor joists that are placed @ 500 crs:

2. Explain briefly as to the positioning of stumps and bearers at Point ‘A’:

3. The size of pine flooring to be used as floor cladding:

Check your findings with the correct answer in the back of this Learner Resource under ‘Learning activity answers’.

* Retain this learning activity as part of your portfolio of evidence.

3. Laying of the floor system

In comparison to many types of traditional and contemporary floor systems, the concrete slab or bearers and joists remain the most widely used flooring system. The building plan details the specification for the strength of the floor, which is based on structural integrity and compliance with accepted construction principles. Each floor system has to be in compliance with all relevant standards, codes, regulations and manufacturer's specifications where applicable.

3.1 Concrete slabs

The most common type of concrete slab is termed, 'slab on ground'.

The slab on ground is designed for the type of structure which is to be supported. As the common styles include either brick veneer or cavity brick, in most cases the design of the slab is standardised.

Construction of the slab is based on a series of edge beams and internal beams which strengthen the slab on its perimeter and loading points of the internal walls, and also to give cross-sectional stability and strength to the slab. The slab on ground is reliant on a vapour barrier or damp proofing membrane, which is placed on a sand fill.

A concrete slab can also be built as a waffle raft, a stiffened raft slab and a footing slab.

In this situation, the construction differs as a close grid of softening ribs support the slab but the complete structure sits on the ground, rather than the slab on ground, where edge beams are excavated and the slab rests on fill.

Slab ready for concrete pour

3.2 Slab check points

1. Plan layout showing the position for all external perimeter beams and internal beams.
2. The sizes of all beams including their spacing and maximum foundation depth.
3. Reinforcement plan showing the size, type and installation details of all sheet mesh, laps, ancillary bars and strategic position of bar chairs or similar supports.
4. Site preparation, including surface gradient, steps and all areas abutting the actual slab preparation.
5. Membrane details including location and special detail for service penetrations. As the membrane is lapped and taped, the details of the moisture control method is provided on the plan specification.

Slab recently stripped of formwork

Timber framing – part house

The slab on ground is designed for the type of structure which it is to support. Here, the stud frame structure is in place for the brick veneer cladding.

Activity 12 - Residential slabs

Using AS 2870 Residential slab and footing code, prepare sketches of stiffened rafts for the following site classifications, types of construction and slab length of 20 metres:

- Class M, Clad frame
- Class S, Articulated masonry veneer
- Class H, Articulated masonry veneer

Prepare sketches ensuring they are fully dimensioned and notated.

Sketch detail to 400 mm above floor level. Ensure you show all detail including:

- edge beam details including height and width of rebate
- slab conditions for an internal load bearing wall
- flashing and weep hole details
- ground level
- concrete cover
- reinforcement.

Check your findings with the correct answer in the back of this Learner Resource under 'Learning activity answers'.

* Retain this learning activity as part of your portfolio of evidence.

Activity 13 - Slab specifications

Answer the following questions:

1. What is the minimum height of the slab on a Class 1 building above finished ground level?

2. Why is it required to specify the above minimum height?

3. What are the minimum concrete covers for reinforcement in a raft slab?

4. What is the function of a vapour barrier?

5. What material is used for vapour barriers?

6. What is the minimum depth of the edge rebate?

7. How far can the timber frame be constructed over the internal edge of the rebate?

8. What is the minimum depth of concrete below the rebate?

Check your findings with the correct answer in the back of this Learner Resource under ‘Learning activity answers’.

* Retain this learning activity as part of your portfolio of evidence.

3.3 Stumps bearers and joists

An alternative to the various types of slab construction is the method of stumps, bearers and joists. This method has been traditionally used and employs the basic principles of column and beam construction requirements and the finished floor level remains clear of the foundation soil.

The stumps made of durable timber of red gum or jarrah can be positioned on the timber sole plates. The alternative type of concrete stump is manufactured from concrete with internal reinforcement.

Stumps are positioned into stump holes and rest on a base of concrete or a pad. Bearers are attached to stumps and secured by either a threaded rod or mild steel rod. Joists are nailed to the bearers in preparation for either sheet platform flooring or tongue and grooved strip flooring.

3.4 Engaged piers

If a building is designed to have concrete strip footings, brick veneer wall and timber load supporting wall, then the brick base structure which rests on the concrete strip footing has engaged brick piers. It is the bearer supported by stumps which rests on the engaged pier of the brick perimeter wall.

3.5 Variations

There are many variations of the standard column and beam principle and methods, such as bored pier footings, pier and beam or steel post resting on pad footings. These offer alternatives in situations where there is undulating land, foundation conditions are considered variable and/or construction is a split level design.

3.6 Laying of the floor system

The laying of the floor system is designed to comply with all standards, codes, regulations and manufacturer's specifications.

The safety standards of all building operations are likewise monitored and approved according to the Occupational Health and Safety Act 2004 (Victoria) and relevant amendments. Other states will have their own health and safety provisions that apply to the building industry.

The floor systems include such types as:

- platform floor (plywood or particle board laid in sheets and glued or nailed to the joists)
- cut in floors (tongue and grooved boards which are fitted into each room and clamped before nailing)
- engineered floor joists – where joists span greater distances than standard construction – an engineered member (joist) is fabricated as an open web, plywood beam or laminated solid beam
- sheet flooring – sheets of water resistant material in timber, fibre or cement based are fastened or glued to supporting structure allowing a firm base for tiling, quarry tiles or similar applied finished compressed sheet wet area flooring
- waterproof sheets of cement based material manufactured in a range of sheet sizes and thicknesses. Fixing of sheets is applicable to regulations of wet area construction. Sheets are bedded and either glued or screwed to the supporting structure. These sheets are often used externally and weatherproofing and weight distribution are additional factors to be included by the building designer/architect.

For details regarding wet area conformance you should refer to BCA, Volume Two, Classes 1 and 10 buildings, Wet area, Part 3.8.1 and Table 3.8.1.1.

For further information make reference to the following texts:

- Building your own home
- Building a house (see ‘Footing Systems’ section)
- Building Code of Australia, Volume Two.

3.6.1 Footings and slabs

Refer to the AS 2870 Residential slabs and footings for details for the construction of residential concrete slabs, strip footings and stump details.

This information is also available in the BCA, Volume Two, Part 3.2.

As the BCA ensures that all footings, slabs and substructures are executed to allow for climatic variations, flexible design and variation in construction practices, where applicable the NCC will refer to the appropriate Australian or New Zealand Standards. However, Deemed to Satisfy provisions or Alternative Solutions give scope to the building designer/architect.

The following NCC, Volume Two, Classes 1 to 10 buildings (Housing provisions) state the options available for various floor systems:

- Part 3.2 Footings and slabs
- Part 3.2.2 Preparation
- Part 3.2.3 Concrete and reinforcement
- Part 3.2.5 Footing and slab construction
- Part 3.3 Contents
- Part 3.3.1.3 Isolated piers
- Part 3.4 Framing

In determining the suitability of floor systems, the following rules apply:

1. Is the system cost effective?
2. Does the system meet all quality requirements?
3. Is the floor system based on performance requirements of Deemed to Satisfy provisions or Alternative Solutions?
4. Are the flooring system materials compliant with all engineering principles of load and force?
5. Are all materials available?

All external base structures require a type of subfloor ventilation, excepting slab on ground.

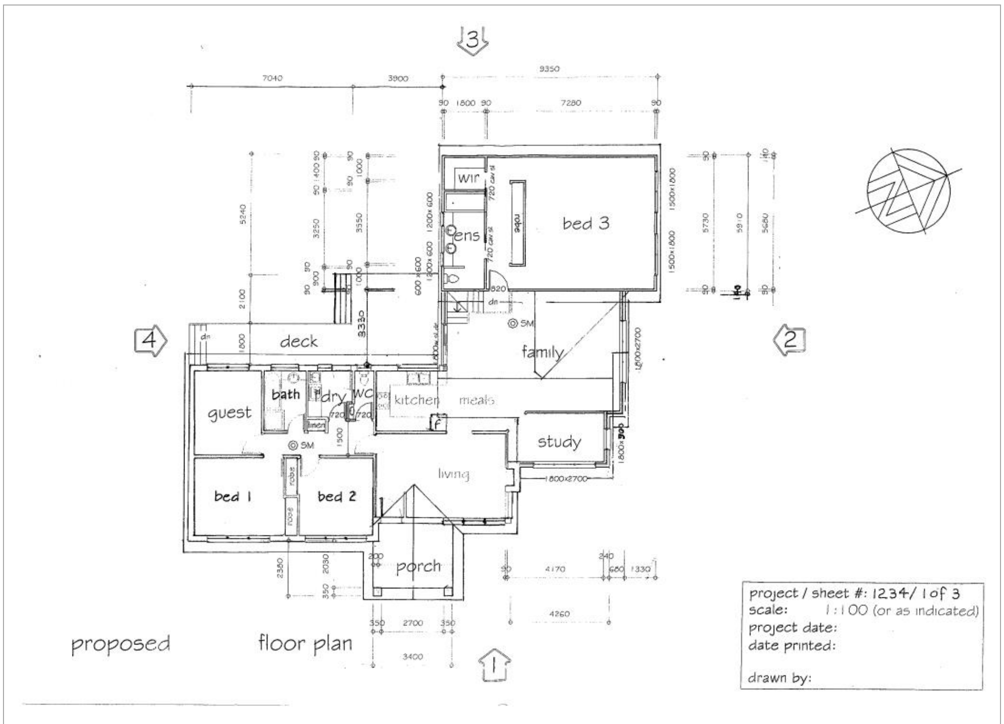
Refer to BCA, Volume Two, Part 3.4 for compliance details of subfloor ventilation.

Activity 14 – Laying the floor system

Using the following information, sketch the subfloor structure for that house.

Clearly set out the foundation (Df), the footing, engaged piers, isolated stumps, bearers and joists for both termite and non-termite areas.

- Class ‘M’ soil
- Articulated BV construction
- Tiled roof on a conventional roof frame
- MGP12 Pinus framing



Determining subfloor structure

To view detail on this plan, you should increase the screen view size on your computer.

Check your findings with the correct answer in the back of this Learner Resource under ‘Learning activity answers’.

* Retain this learning activity as part of your portfolio of evidence.

4. Structural and non-structural wall systems

Before the actual construction process commences, the building designer/ architect identifies and analyses the technical construction principles and material performance.

Typical materials used in structural and non-structural buildings include timber, cavity brick, concrete block and structural steel, although these materials are not limited.

Many buildings utilise a combination of materials and this type of composite construction is beneficial in providing cost savings, increased thermal and acoustic efficiency and often ease of construction.

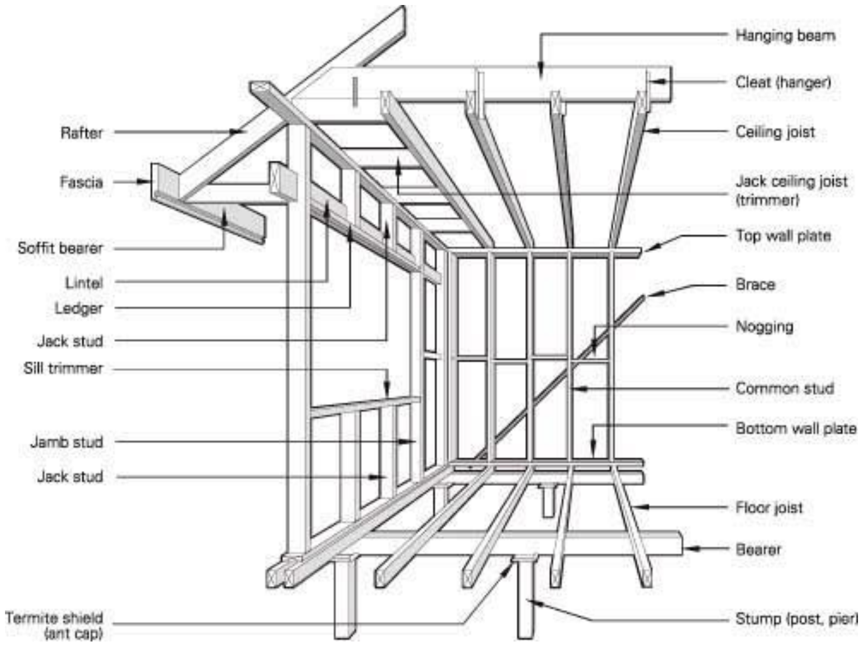
4.1 Framing

The following information is supplied by the Department of Climate Change and Energy Efficiency and is from *Australia's guide to environmentally friendly homes*.

> *Typical lightweight timber construction consists of framed and braced structures with applied claddings. The type of framing can range from large, widely spaced timbers to the closely spaced light timbers commonly seen in stud frame construction. The process of construction may begin with a concrete slab onto which continuous frames are fixed, or placement of piers or pad footings to carry posts or bearers.*
>
> *Timber components may be fabricated off or on-site. Modern construction techniques in Australia generally favour off-site fabrication of items like trusses, with the extent of on-site fabrication of elements like stud frames being dependent on individual designs.*

4.1.1 Typical frame details

The timber framing construction is regulated under the NCC and typical details are provided in AS 1684 Residential timber framed construction. All structural design should be prepared by a competent person and may require preparation or checking by a qualified engineer. Qualified professionals, architects and designers provide years of experience and access to intellectual property that has the potential to save house builders time and money as well as help ensure environmental performance.



Typical timber frame construction

For a conventional house, a timber frame can be described as a skeleton of timber components to which is attached exterior wall claddings, internal linings, flooring, roofing, windows and doors.

The timber frames that are designed and built to AS 1684 Residential timber framed construction will comply with the NCC requirements, except when designed and built in areas subject to seismic activity, for which the NCC provides additional fixing and construction requirements.

For unconventional timber framed housing, the approving authority will accept that AS 1720 Timber structures code can be utilised in design, but will need some professional expertise to verify that the proposed design meets statutory requirements.

Joints and connections

There are many types of traditional joints and a professional joiner or carpenter will use the most appropriate for a specific construction.

Timber frames and trusses can also be purchased already fabricated. A common joining system is a nail plate that is a metal plate with integral nail shapes, or holes for nails, designed to join the timbers together.

You should always be alert to the emergence of new systems, new building codes or regulations and innovation, such as the engineered timber products.

4.2 Bracing

In timber construction, the timber wall framing requires bracing and in Australian construction, the bracing material can include timber bracing checked into the frame at the appropriate angle 45°. Other types of bracing include speed bracing of galvanised metal angle, which can be slotted into the frame at 45°, as per the timber brace. Metal strap brace is also an option, providing the brace is positioned and tensioned prior to fastening.

As many timber walls have a number of closely spaced door openings, the standard diagonal bracing has been largely superseded by steel bracing. Plywood sheet bracing can be used as the prepared method for the complete frame or can be used in combination with other bracing types.

As in brick veneer construction, the timber wall is the load bearing structure and thus, all bracing requirements mirror those of the timber built house with cladding.

AS 1684.4 Residential timber framed construction (simplified non-cyclonic areas) covers bracing in Part 8.3.2.2.

Any large area of framework which, subject to racking or destruction, must be properly braced and this includes floor/base structures, walls and roof.

4.2.1 Fastening methods

Regardless of which material or fastening is used, the structural integrity of the bracing system is entirely dependent on the placement of the fastenings or anchorage methods.

In the case of metal framework, the bracing must be fastened to prevent electrolysis or rust. Conventional diagonal bracing by timber, metal angle or strap equally has to be manufactured or machined to correct dimensions.

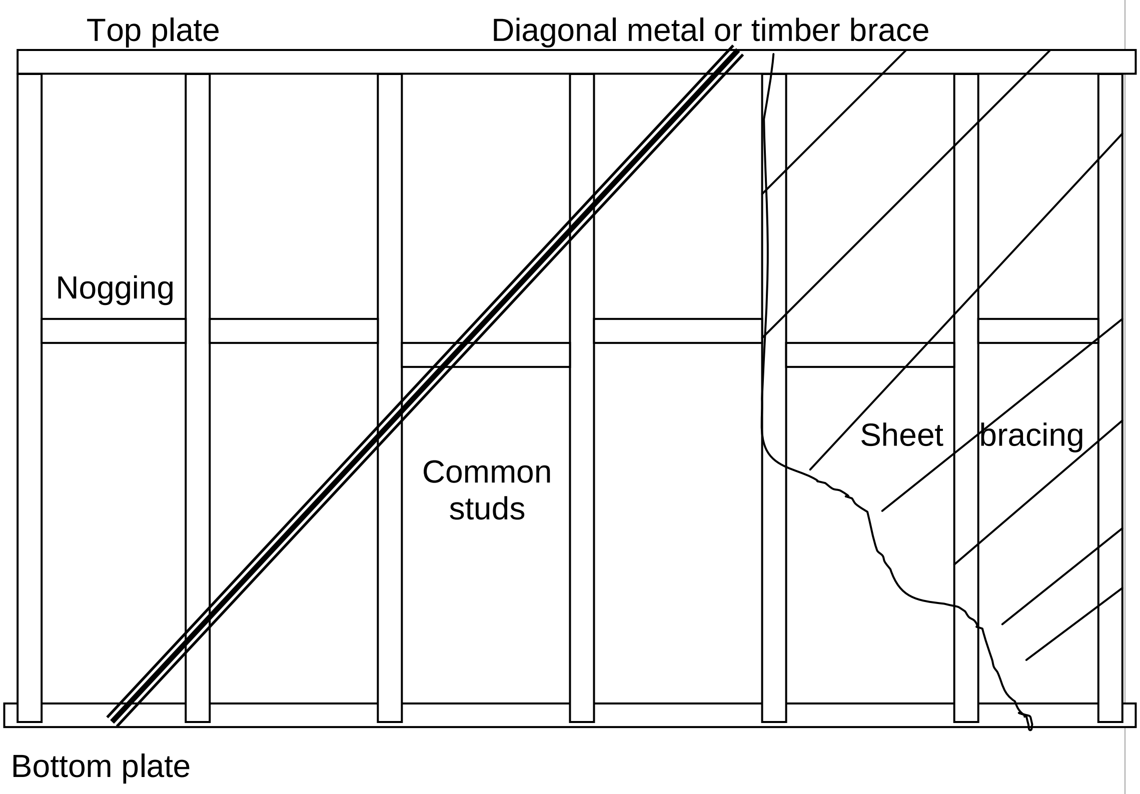
4.2.2 Bracing preferences

As bracing forms a critical part of the structural integrity of the frame, the building designer/architect will follow standard construction practices and compliance with regulations, codes and manufacturer's specifications.

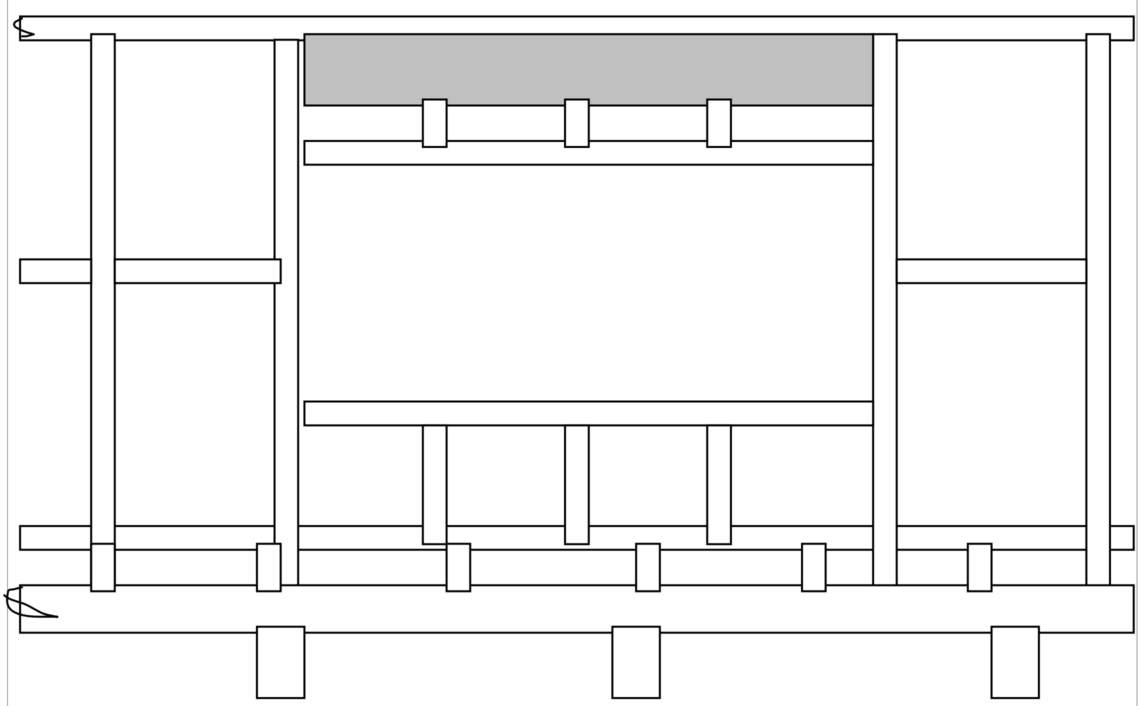
AS 1684.4 Residential timber framed construction is used by the builder and his subcontractors on the site. However, for design purposes, AS 1684.2 is used by engineers in Victoria. These two standards provide the design of framing members for buildings in Class N1 and N2 wind areas.

In other states or where the proposed dwelling faces onto open areas, AS 1684.1 and AS 1684.3 Residential timber framed construction for cyclonic areas of Australia will be used.

Gable roofs require bracing whereas pitched or trussed roofs of hip and valley are self-braced.



Typical wall framing with bracing



Frame including opening for window – no bracing required

In all structures, the legislative and manufacturer's specification should be checked. The wall and roof components comprising bracing, tie downs and reinforcement must be complied with. Particularly, there should be strict adherence to confirmation with tolerances, allowances and installation of fixing methods must be followed.

The BCA states within its functional statement that, 'A building or structure is able to withstand the combination of loads and other actions to which it may be reasonably subjected.'

In the BCA performance statement, the structural stability and resistance to actions is based on recognition of dead loads, live loads and actions such as wind, earthquake and other courses.

(Reference: NCC, Part 2.1 (b) pages 53 – 54).

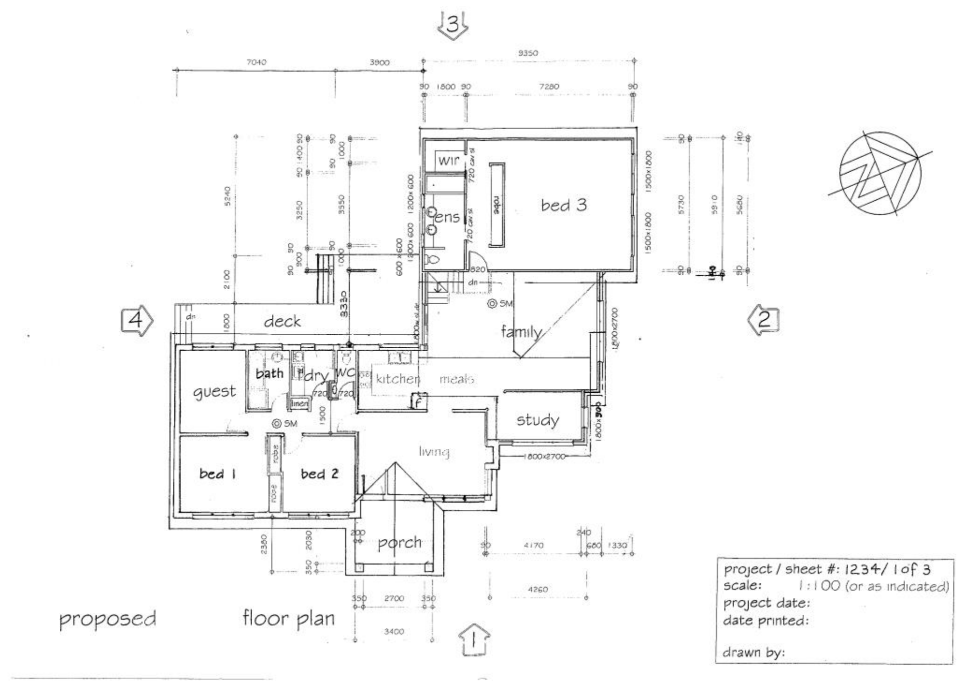
Activity 15 – Bracing requirements

For this learning activity,use the floor plan and indicate two directions of where the wind might come from towards the house.

Now by using the process to determine wind bracing from AS 1684.4, Part 8.3.2.2 and 8.3.2.3, determine the bracing requirements for that house.

Refer to 8.3.2.4 and .5 before using Table 8.3 to select and then place your selected type of bracing, ie the number of units required.

As you are locating the bracing, refer to Part 8.3.2.6 and Table 8.4 for rules relating to the distribution of bracing.



Determining bracing requirements

To view detail on this plan, you should increase the screen view size on your computer.

Check your findings with the correct answer in the back of this Learner Resource under ‘Learning activity answers’.

* Retain this learning activity as part of your portfolio of evidence.

4.3 Base structure, walls and roofs

Low rise residential buildings utilise many types of structural timbers in base structure, walls and roofs.

AS 1684 Residential timber framed construction – non-cyclonic areas lists the considerations for design. The logical sequence for a building designer/architect is to initially establish the factors of wind and terrain.

Design considerations include the following elements:

1. The wind classification as listed in AS 1170 Structural design actions or AS 4055 Wind loads for housing, or as stated by the relevant authority.
2. The extent and preliminary location of bracing for floor, walls and roof.
3. The sizes and profiles of bracing members.
4. The type of bracing system as designed for the structure.
5. The method of preventing uplift including all connections and tie downs.

Refer to the NCC, Volume Two, Part 3.4.3 Timber framing.

Appropriate performance requirements

Where an alternative timber framing design is proposed as an Alternative Solution to that described in Part 3.4.3, that proposal must comply with:

- performance requirement P2.1
- the relevant performance requirements determined in accordance with 1.0.10.

Acceptable construction manuals

- Part 3.4.3.0
- Performance requirement P2.1 is satisfied for a timber frame if it is designed and constructed in accordance with the following, as appropriate:
  - AS 1684.2 Residential timber framed construction – non-cyclonic areas
  - AS 1684.4 Residential timber framed construction – simplified – non-cyclonic areas

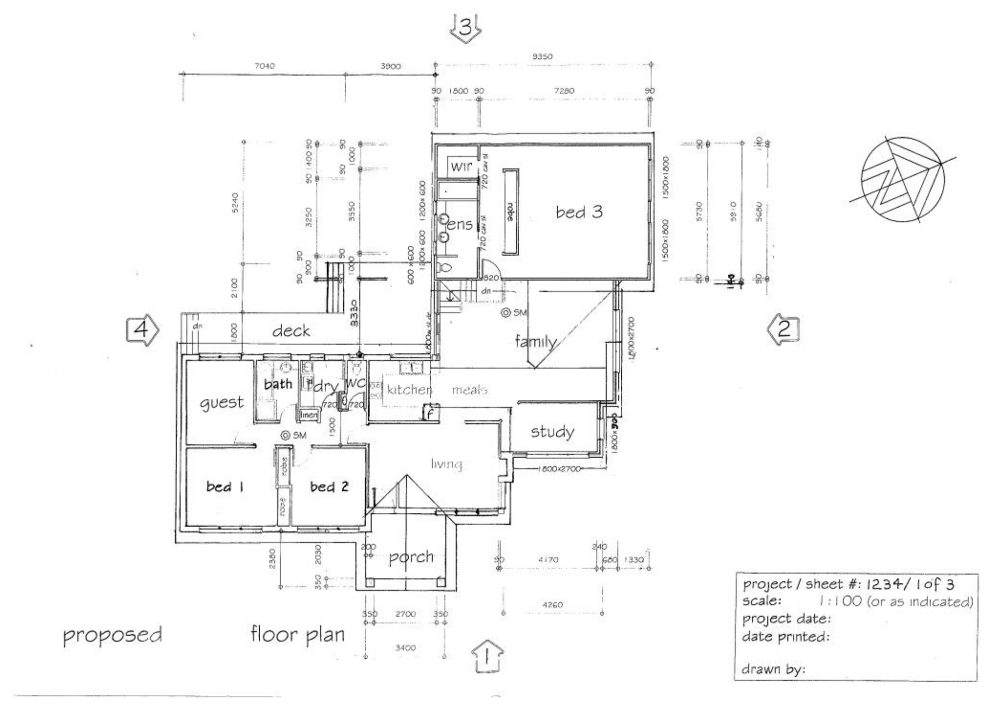
4.4 Floor framing

Bearers, joists, flooring, wall framing and roof framing form part of the structural timber amalgam. Elements such as spacing, cantilevers, engineered timber products and fixing or attachment methods of all components are tabled in AS 1684.2 Residential timber framed construction – non-cyclonic areas, and should provide the standard references for structural timber design.

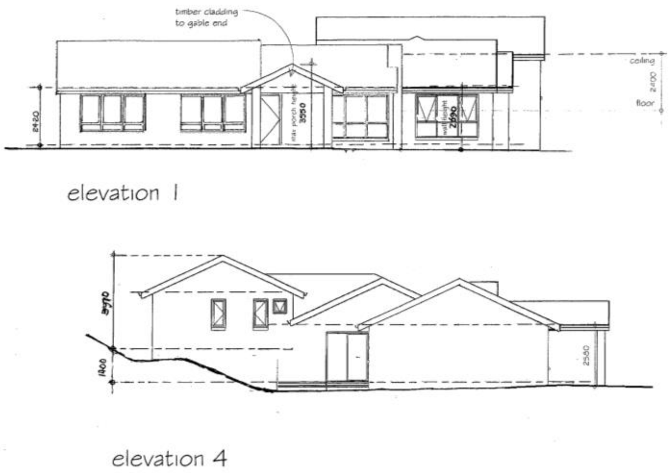
Long span 'deep' manufactured floor joists

Activity 16 – Structural timber members

Using the house floor plan and elevations, design all the timber members to construct that house from bearers and floor joists, walls and their structure and timbers for a conventional roof frame.



Determining structural timber requirements



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Elevations

To view detail on these plans, you should increase the screen view size on your computer.

Check your findings with the correct answer in the back of this Learner Resource under ‘Learning activity answers’.

* Retain this learning activity as part of your portfolio of evidence.

4.5. Quality of the frame

There are many manufacturing processes in which a quality frame can be produced by using common methods, such as factory pre-cut and pre-nailed, or factory pre-cut and assembled, or alternatively, the frame components are assembled on-site.

The common practice for factory assembled frames and trusses are to use stress graded timber to AS 1684.2 Residential timber framed construction – non-cyclonic areas, Table 1.2 stress grades.

If the frames require pre-fabricated components such as roof trusses, glued and laminated beams and links, any nail plated jointed timbers can be used.

Factory operation ensures the frame is located in jigs and the entire structure is pre-fabricated into modular form, and is ready for transportation to the site.

Attaching the 'barge boards'

Activity 17 - Frame quality

Sketch one wall of your house, preferably with various opening widths, and design two wall frames from F8 OBHW and MGP12 Pine.

Include a door width 1200 mm wide and a window with an opening size of 2700 mm.

Check your findings with the correct answer in the back of this Learner Resource under 'Learning activity answers'.

* Retain this learning activity as part of your portfolio of evidence.

4.6 Waterproof membrane

Membrane means a barrier impervious to water.

AS 3740 Waterproofing of wet areas in residential buildings establishes the performance requirement for wet areas in Classes 1 and 10 buildings as set out in Table 3.8.1.2 of the NCC, Volume Two.

Part 3.8.1.3 Materials – Waterproof

For the purpose of this part, the following materials used in waterproofing systems are deemed to be waterproof:

- stainless steel
- copper – material not less than 99.9% copper
- waterproof flexible sheet flooring material with sealed joints
- membranes meeting the requirements of AS/NZS 4858.

Activity 18 - Waterproof membrane

Sketch the wall of a bath hob where it returns down to a polymarble shower base.

Show all framing members, the wall lining, the selected wall finish, all flashings and sealants.

Refer to BCA, Volume Two, Part 3.8.

Check your findings with the correct answer in the back of this Learner Resource under ‘Learning activity answers’.

* Retain this learning activity as part of your portfolio of evidence.

4.7 Allowances for relevant services

In carrying out the plumbing and drainage work on a building project, the Plumber has to deal with complex hot and cold water, gas, sewerage and drainage that are detailed on the contract documentation which includes the specification, manufacturer's details and plumbing legislation.

4.7.1 Water quality

The basic requirement of a plumbing system is to provide good quality water to the occupants of the building.

Water is classified by hardness, and this depends upon the amount of dissolved salts in the water. These categories are:

- soft
- medium
- hard
- very hard.

4.7.2 Building equipment

- Boilers fired by oil or gas
- Hot water tanks – instantaneous and non-storage and storage systems
- Circulation pumps
- Expansion tanks
- Venting
- Automatic electrical controls

4.7.3 Electrical

- All electrical work is subject to codes, regulations and standards, with each state having its own 'wiring regulations'.
- AS 3000 governs the installation of the building's entire work.
- In most cases throughout Australia, we use mains power that is supplied to us at 240 volts – single phase connection. Industry has their power supplied in three phase power.
- Connections to our property are both underground and overhead, with the latter fast disappearing.

4.7.4 Communication systems

- Today, there is a large range of complex electronic communication equipment available to industry and the public.
- Within large buildings and to the outside, communications is integrated into the telephone system. Here, we have two main branch exchanges:
  - PABX or private automatic branch exchange
  - PMBX or private manual branch exchange used for a for a small number of external lines.

4.7.5 Exhaust systems

- The Australian Standard for the use of mechanical ventilation and air conditioning in buildings is AS 1668. AS 1688.2 sets out the requirements for air handling systems that ventilate enclosed spaces by mechanical means. It sets the minimum requirements for preventing an excess of airborne pollutants and odours.
- It does not prescribe the requirements associated with a person's comfort such as:
  - temperature
  - humidity
  - air movement
  - noise.
- Natural ventilation in buildings is created by:
  - the difference in temperature between the air inside the building and outside the building
  - wind pressure.
- Mechanical ventilation systems have two main components:
  - pipes or ducts used to distribute the fresh air from outside the building
  - fans and other equipment which provide the power to move the fresh air around the building

It is important in the design of the exhaust system to make sure that expelling air from one fan isn't being drawn in by another fan.

4.7.6 Ducting for heating and cooling

- BCA, Volume Two, Part 3.7.1.9 Flexible ductwork used for the transfer of products initiating from a heat source that contains a frame must comply with the fire hazard properties set out in AS 4254.
- BCA, Volume One – J5.2 Air conditioning and ventilation systems must have any ductwork insulated and sealed in accordance with specification J5.2.

4.7.7 Passive and active fire detection and prevention systems

- Passive systems
  - BCA, Volume One, Part C2 defines the separation requirements of buildings in case of fire. Stairwells and lifts must not be in the same shaft if the stairway is a fire exit.
  - The class of occupancy largely determines the fire separation requirements:

Class	Type of building
1	House
2	Flats and units
3	Hotel or motel
4	Residential parts of Classes 5 to 9 buildings
5	Offices
6	Shops
7	Warehouses and carparks
8	Laboratories and factories
9	Public building
10	Outbuildings

Fire resistant materials and construction methods are used so that fire can be contained within a building or within a fire compartment. This stops the fire spreading to other parts of a building or to neighbouring buildings.

These construction systems are specified in terms of its fire resistant level or FRL. The FRL defines the structure in terms of its ability to restrict the spread of fire. The BCA stipulates the fire resistance level necessary for:

- Separating wall/floor systems:
  - roofs
  - columns
  - beams.

  There are numerous materials used to increase the FRL rating of a structure.

  Pre-fabricated fire door sets and access panels are available in varying fire resistance levels.
- Active systems

  An active fire control system may involve one or all of the following:
  - portable fire extinguishers
  - fire hydrants
  - sprinkler systems
  - smoke control
  - water supplies to fire system.

The height of the building is particularly significant when determining the fire fighting equipment needed. In Australia, fire can only be fought from outside the building using ladders and hoses if the building is less than 25 metres high. A fire in the taller buildings, above 25 metres must be fought from within.

For this reason, high rise buildings are fitted with sprinkler systems and emergency lifts.

Fires are classified into six different classes depending on the type of materials involved:

- Class A – Involves the burning of solid materials such as: wood, paper, plastics, fibre.
- Class B – Involves burning liquids or liquefiable solids such as: petrol, acetone, paints, polystyrene, ethanol.
- Class C – Involves gases such as methane, propane, butane.
- Class D – Involves metals such as sodium, potassium, iron fittings, aluminium dust.
- Electrical – There is no specific class for electrical fires as electricity itself does not burn. However, fires caused by electricity are often referred to as 'Class E' fires.
- Class F – Fires, involve burning, cooking oils and fats.

Smoke control and containment systems

Smoke spreads low and across the room or area away from the fire source, and this in itself can cause a large amount of damage.

Smoke can cause fire, damage equipment, set off other fire fighting alarm systems and cause asphyxiation to people in the area.

Refer to NCC, Volume One, Part E2.

Powered systems for operating doors and windows

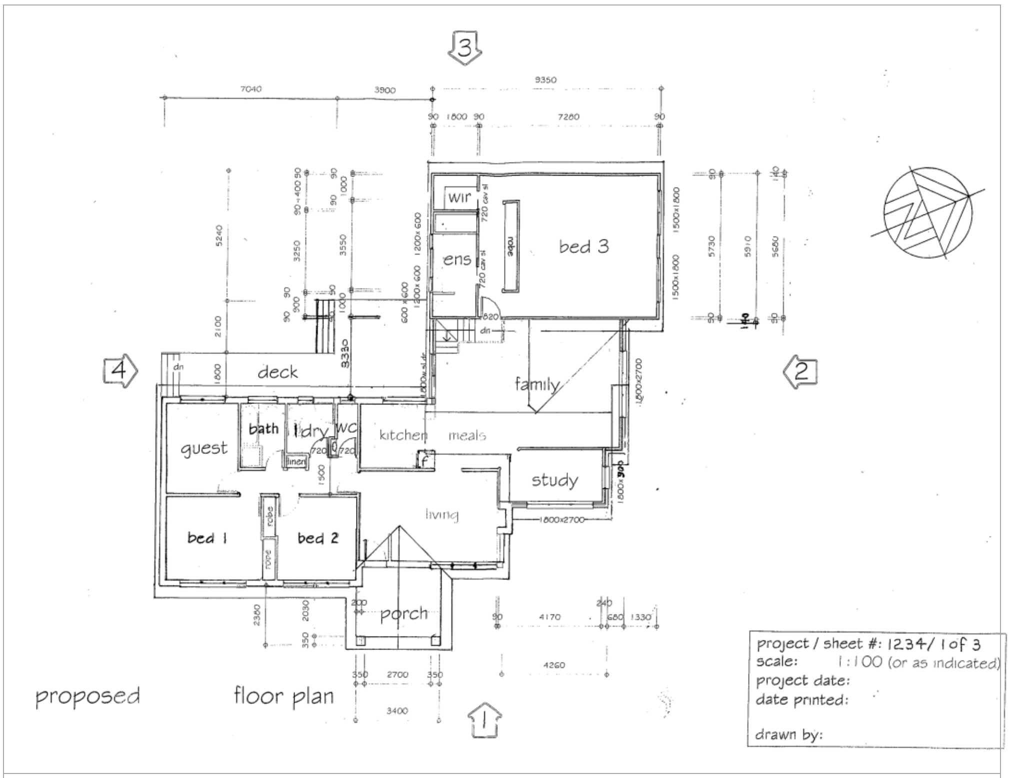
An exit door, power operated:

- Must be able to be opened manually under a force of not more than 110N if there is a malfunction or failure of the power source.
- If it leads directly onto a road or open space, it must open automatically. If there is a power failure to the door or an activation of a fire or smoke alarm anywhere in the fire compartment served by the door.

Refer to BCA, Volume One, Part D2.19.

Activity 19 – Allowances for relevant services

Using the following plan and relevant codes and standards, show where relevant services are to be installed.



Identifying services

To view detail on this plan, you should increase the screen view size on your computer.

Check your findings with the correct answer in the back of this Learner Resource under 'Learning activity answers'.

* Retain this learning activity as part of your portfolio of evidence.

5. Building of a roof system

The structural integrity of the roof system components as specified in the building plan must comply with relevant codes and accepted industry construction principles.

As the various types of roof configuration can include hip and valley, Dutch hip, Dutch gable, north light, gable end, dual pitch, box gable and skill on the manufactured roof trusses must consistently form the deserved roof shape, whilst simultaneously retaining sound design principles.

5.1 Loadings based on design criteria

The AS 1684.2 Residential timber framed construction – non-cyclonic areas and AS 1720.1 Timber structures – design methods determine the design principles of pressure, loads, forces and capacities.

The predominant factor in roof truss design and installation is that it must allow for the wind force combinations and these include:

- racking, where the walls deform
- overtwining, where the walls move horizontally sideways
- uplift, the uplift force causes connection failure and the roof is torn upwards from its anchorage point on the walls.

Other factors also influence the safety and stability of the roof, such as the stress grade of the timber used in truss construction, excessive live and dead loads, earthquake zones and the initial stability of the structure on which the roof is to be placed.

Check that trusses have been designed and manufactured to the exact building specifications. Such items as eave overhang, roof pitch, roof covering, ceiling lining and loads need to be known by the truss fabrication. Most designs are computer generated and truss drawings carry an engineering compliance stamp.

5.2 Truss erection

The truss erection is planned, implemented and checked in accordance with:

- the building plan requirement
- the type of roof being constructed
- the relevant codes and accepted industry construction principles.

5.2.1 The truss units

The basic components of the truss include the top chords, bottom chords, web members and connection points.

As trusses are designed to carry the roof over a wide span without intermediate support, the internal walls which contact the bottom chord must be non-load bearing.

Whilst the truss is a load bearing structure, the deflection allowance, strength of component parts and joint design details must strictly conform with the design parameters.

5.2.2 Transporting and handling trusses

All trusses should be transported, stood and stacked, carried, lifted and fixed in accordance with strict manufacturer's specifications and safety codes.

Trusses are designed to withstand the stresses of normal transporting and providing they are properly stacked, stored and lifted, the truss will retain its engineered shape and structure.

The shape of the trusses includes the apex, designed web lifting points and web layout. Depending on the size and type of building operation, there are often drawings which show the method, sequence and connection points for lifting.

As the installation of trussed roof is deemed to be hazardous, the duties of the employer and employees, the designers of buildings or structures need to ensure that all safety requirements are compliant with the relevant Occupational Health and Safety Act in the state/territory, eg Occupational Health and Safety Act 2004 (Victoria).

Reference: BCA, Section Division 2, Part 21, 22 and 23, and Division 5, Parts 28 – 32.

5.3 Truss quality, types and principles

As trusses are an engineered component, the processes, which are planned and implemented, must conform to all aspects of a quality product.

The structural principle of a roof truss is that they can carry a roof over a wide span without the need for any intermediate supports. Their main feature is that they have a clear span and thus, are particularly suitable for domestic and industrial/commercial buildings. Houses, schools, public buildings and sports venues, such as swimming pools can utilise the clear span truss principles.

Because the truss is a load bearing structure, the limits of structural deflection are designed in the truss unit and all chords, joints and configurations assist in ensuring the truss functions at full strength.

5.3.1 Truss general principles

The simplest form of triangular shaped trusses rely on the following design and manufacturing principles:

- Span – the distance overall to the outside supporting top plates.
- Pitch or slope of the top chords which give the truss its distinctive triangular shape.
- Spacing at which the trusses are to be positioned on top plates.
- Type of roof covering and ceiling material.
- The horizontal overhang of the top chord.

Most truss manufacturer's prefer to measure the span and other building components from the actual job. The working drawings do clearly indicate the design and type of trusses required, but slight discrepancies in spans of the actual job can result in the trusses being unsuitable for the project. Trusses cannot be altered, cut or modified in any way, unlike a conventional pitched roof.

5.3.2 Truss configurations

Common truss types include:

- cantilevered
- sail-over
- scissor
- truncated
- hip and lock.

The versatility of trusses enables an almost limitless range of shapes, sizes and spans in manufacture.

Dependant on the type of truss used, some form of wind bracing is required to counteract the wind forces and the potential lateral buckling of the top chord.

Setting out the roof trusses

Standing the wall frames

5.3.3 Truss anchorage

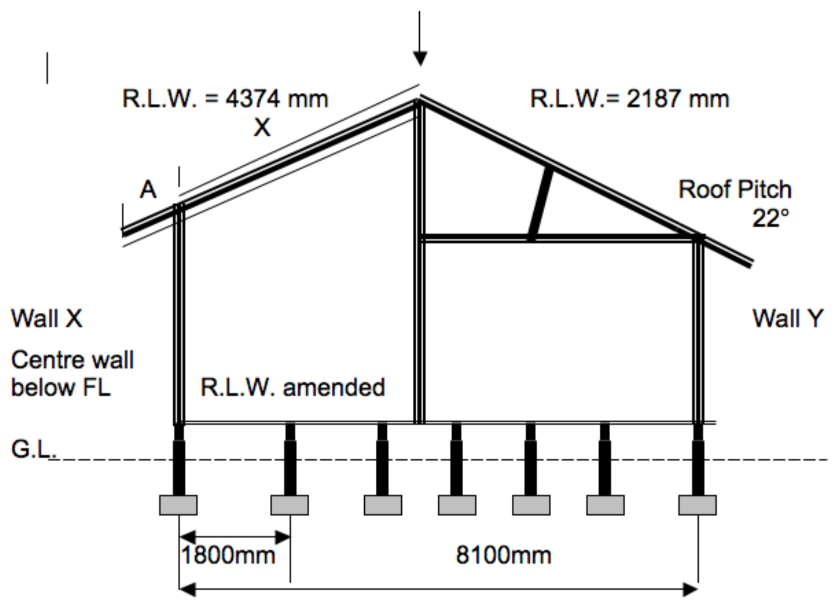
Trusses are secured to the top plates by nails, plates or design anchors. The strength of the top plate is essential. The forces the plate will be subjected to are primarily wind and uplift. Tie downs are specified in the BCA and working drawing details.

In a load bearing wall frame, special consideration needs to be given to:

- the lintel sizes over openings
- the size of the top plate
- any part of the support structure which will support extra load.

Activity 20 - Truss calculations

If stumps are placed under 100 x 75 F8 bearers which will be carrying a suspended floor system as shown below:



Calculations

Calculate the following:

1. Size of the MGP12 rafter of the cathedral roof section of the roof. Rafter length = 4300 mm.

2. Size of the MGP10 rafter of the pitched and propped section of the roof. Rafter length = 4450 mm.

Check your findings with the correct answer in the back of this Learner Resource under 'Learning activity answers'.

* Retain this learning activity as part of your portfolio of evidence.

5.4 Roof sarking and cladding

General pitched roof construction can be accomplished by using pitched and propped construction whereby each roofing member is then referred to as ‘pitched’.

The alternative method is by using roof trusses, which are factory manufactured, engineered and often delivered to site and hoisted into position.

Both roof types can utilise a variety of roof coverings including slate, tiles, shingles or slate.

Roof framed

5.4.1 Sarking

Sarking is recommended under most roofing coverings because of its ability to perform a dual role. In the first instance, the sarking acts as a secondary protection against the penetration of moisture caused by wind-blown spray, leakage and condensation from poorly fitted tiles or metal roofs.

In the second instance, the sarking material is usually manufactured as a double sided flexible sheet material which can be rolled into position, fitted beneath the roof battens and lapped into correct sequence. Because the sarking has one reflective side and one matt side, the reflective side is fitted to reflect the radiant heat of the sun.

The BCA details the mandatory requirements of roof covering and sarking by:

- Reference: BCA, Volume Two, Part 3.5.10 Acceptable construction manuals
- Reference: BCA, Volume Two, Part 3.5.11 Acceptable construction practice

Roof tiler – loading the roof

5.4.2 Roofing tie downs

For buildings, which are constructed in an area classified as 'high wind', the structure must have sufficient strength to transfer the forces to the ground. Buildings can slide off their foundations or can be lifted or separated. In most cases, the extreme movement of the building ultimately causes collapse.

Reference: BCA, Volume Two, page 480, Construction in high wind areas and anchorage.

Tie down types

As tie downs can take the form of rods placed through the wall from footing to top plate, stoops are connected to brickwork and transfer loads down the wall. Miscellaneous types of proprietary line brackets which are not only attached to the framing and roofing members together, but also assist in the transference of load to the foundation.

5.4.3 Legislative requirements

The building or structure must meet the appropriate performance requirement and this can be achieved by adherence to acceptable construction manuals in Part 3.11.1, Resistant to actions, Part 3.11.2 and 3.11.3. See AS/NZS 1170.0 Structural design actions.

Overall, the BCA, Volume Two makes reference to Part 3.11, Structural design manuals and the references give practical guidance which makes allowance for variations in climate and changes to geological or conditions in different geographical conditions.

5.5 Working at heights

In the process of carrying out roofing work, the hazards caused by working at heights are far more prevalent than when working with other construction practices in the building.

Working on a roof requires fall protection

As all contractors and work personnel must have the required skills and knowledge to undertake such work, the following elements need to be checked prior to construction.

1. Have all the appropriate codes and standards been met? (**Note** that the NCC includes both Australian Standards and New Zealand Standards.)

2. Have the manufacturer's specifications been checked in compliance with all elements of the building designer/architect specifications and working drawings?

3. Does the structure meet all structural principles as listed in the BCA and engineering shop drawings?

4. Has the project been planned to select all structural elements based on relevant structural member dimensions and installation specifications?

5. Does the project include an evaluation and self-management strategy to ensure that all processes are implemented according to plan and specifications?

6. Is the concept of innovation, new technology and effective construction practices being applied?

7. Has the whole project been planned in accordance with safe working practices and in particular, the relevant OHS legislation (eg Occupational Health and Safety Act 2004 (Victoria)) and appropriate Code of Practice where applicable?

Activity 21 - Bracing

Explain why it is necessary to fix bracing to timber frames.

Check your findings with the correct answer in the back of this Learner Resource under ‘Learning activity answers’.

* Retain this learning activity as part of your portfolio of evidence.

6. External wall cladding

Cladding is used for bracing the structure and includes material such as:

- weatherboards
- brick veneer
- fibre cement or compressed wood panelling
- coatings over base material
- colorbond or zinc/aluminium sheeting.

All cladding types are assessed for their compliance with relevant codes, manufacturer's specifications and accepted industry construction principles.

Bricklayer loading the job

6.1 Bracing

Regardless of which types of bracing and configuration are used, the basic principle of a structural wall cladding is to counteract the racking and shear forces imposed on the walls of the structure.

The cladding is designated as 'permanent bracing' and is designed to resist the 'racking forces' of the building. These forces occur in the horizontal plane and it is only by using the types of cladding connections and designed placement of cladding mass that the racking forces can be minimised.

If a building is to be structurally braced by any type of cladding material, the vertical plane bracing must be evenly distributed around the perimeter of the structure.

Bracing in place

6.2 Wind forces

As wind forces affect the vertical claddings, there are also the standard design elements of most conventional buildings, where there are a number of horizontal surfaces referred to as diaphragms and these include roof, floors and ceilings.

As the force of the wind is applied to each level, the racking forces transfer through the bracing directly to the substructure and foundation.

6.3 General requirements

In accordance with AS 1684.2 Residential timber framed construction – non-cyclonic areas, the bracing requirements are based on three factors:

- The wind pressure on the building
- The area of elevation
- The racking forces.

To design an effective structural cladding, the following procedures can be adopted:

- Determine the wind classification by reference to AS 4055 Wind loads for housing and AS/NZ 1170.2 Structural design actions – wind actions.
- Determine the wind pressure by the wind classification and building width. See Tables 8.1 to 8.5 of AS 1684.2 Residential timber framed construction – non-cyclonic areas.
- Determine the elevation by calculating the worst direction of wind on the structure and bracing can then be designed for the most adverse situation. See Table 8.3.6.6 in AS 1684.2 Residential timber framed construction – non-cyclonic areas.
- Calculate the racking force by taking into account the long and short sides of the building. The racking forces in kN can be calculated by multiplying the area of elevation in m^2 x wind pressure (kPa). See Tables 8.1 to 8.6 in AS 1684.2 Residential timber framed construction – non-cyclonic areas.
- Design bracing systems for walls and check connections, distribution and spacing of all components. See Table 8.3.6 in AS 1684.2 Residential timber framed construction – non-cyclonic areas.

6.4 Compliance

Structural bracing in the form of cladding is described in AS 1684 Residential timber framed construction – design criteria, but in addition is referred to in the BCA, Volume Two.

To comply with BCA requirements, both the appropriate performance requirements and acceptable construction practices must be rated.

6.4.1 Appropriate performance requirement

Whilst there are accepted types of cladding materials, if an alternative cladding type is used, the BCA classifies this option as an 'Alternative Solution'. A proposal to adopt an Alternative Solution, must comply with BCA:

- Performance requirement P2.1
- Performance requirement P2.2.2
- The relevant performance requirements with 1.0.10.

The weatherboards which provide the covering are usually profiled as square edge, round edge or rusticated. As the boards are lapped, the nailing or fixing requirements are specified to ensure fixings occur in the correct section of lap, and all weatherboard internal and external corners are mitred or butted into a weatherboard stop.

Australian weatherboard construction uses common timber species, including hardwood, cypress pine, treated pine, western red cedar and baltic pine.

The BCA determine the appropriate weatherboard laps based on type of species. (Reference: BCA, Volume Two, Section 3.5.3.2).

In addition, spacing of fixings and type of nail used to fix weatherboards are detailed in BCA, Volume Two, Section 3.5.3.2: c, d and e, and figure 3.5.3.1 – diagram A.

6.5 Installation of cladding

The installation of cladding as specified in the building plan is required to be properly supervised and checked to all standards and accepted industry construction principles.

6.5.1 Weatherboard cladding

It is a fundamental step in placing weatherboards that they are securely fastened, are consistently lapped and positioned in a true horizontal and level plane and provide a weatherproof and aesthetic finish to the exterior of the dwelling.

A front entry

Weatherboards are usually positioned on a plinth which is nailed to the perimeter of the building with either mitred or butted corner joints. The plinth actually forms the demarcation line between the base structure and the wall section.

A timber deck

All claddings must comply with the OHS legislative requirements (eg Occupational Health Safety Act 2004 (Victoria)), and in Victoria particularly, installation involving employers, employees and suppliers of plant should plan the site in compliance with Occupational Health Safety Act 2004 (Victoria), Divisions 1, 2, 3, 4 and 5.

6.5.2 Additional weatherboard types

Weatherboards can also be manufactured in fibre cement and these can be fixed to the frame in a variety of ways as designated in BCA, Volume One, Sections 3.5.3.3 and 3.5.3.1 – diagram 13.

There are some differences between fixing boards to timber studs and alternatively, steel studs.

6.5.3 Brick veneer (masonry walls)

Brick veneer construction relies on the framework of timber or metal carrying the load of the structure whilst the veneer of masonry forms the outside cover.

Ready for the roof

The veneer is primarily a skin which is held to the framework by wall ties strategically placed to allow for the movement forces on the masonry skin.

As the skin imposes a considerable dead load, the strip footings or concrete slab on ground is designed and reinforced to allow for these loads.

In addition to the actual positioning of the veneer, skin allowance has to be made for moisture within the wall and rising dampness.

Wall ties and DPC are provided to allow for moisture movement and are fixed to either plan specifications or manufacturer's special details.

Standing the frames

There is the mandatory requirement that all buildings in BCA, Volume Two, Classes 1 and 10, conform to the acceptable construction practices.

The BCA requirements of masonry construction are cross-referenced with the appropriate standards. Options within the BCA can offer building within the performance requirement of:

- acceptable construction manual
- acceptable construction practice.

As with other types of construction within the BCA, there is also a provision for Alternative Solutions and these are deemed as appropriate performance requirements.

Sheet bracing to the corners

6.5.4 Building Code of Australia compliance

Part 3.3 of the BCA details the many components which from the veneer wall and generally take into account:

- the strength and composition of the mortar
- the fixings allowed for tie downs to prevent wind damage and displacement
- the lintels attached to the structure to carry the load of the building over openings
- the waterproofing methods of damp proof courses and flashings.

(Reference: NCC, Volume Two, Part 3.3 – 3.3.1, 3.3.2, 3.3.3 and 3.3.4)

Definitions in NCC, Volume Two, Part 3.3 form an integral part of the explanations used in the remainder of Part 3.3.

6.5.5 Safety precautions

Brick veneer construction has many unique hazards and compliance with the site safety plan and the OHS legislation (eg Occupational Health and Safety Act 2004 (Victoria)) is mandatory.

Prior to establishing a safety plan for any construction, check the OHS duties of both employers and employees (eg in Victoria, this means checking the Occupational Health Safety Act 2004 (Victoria) for the Duties of Employers, Part 2.1 and Duties of Employers, Part 2.5).

6.5.6 Coatings over base material

There are many alternative types of base materials which can be fixed to a framework and then weatherproofed to a designated standard.

Both fibre cement sheeting and polystyrene sheets are alternative cladding methods which are readily attached and offer a degree of thermal, acoustic and aesthetic advantage.

Regardless of which cladding material is chosen, the sheets are required to be covered or rendered in either a natural cement render, or synthetic covering applied by roller, spray, brush or trowel.

The rendered finish is generally coloured and waterproof and retains a textured finish.

All application is done to manufacturer’s specifications and design standards.

Alternative finish types are subject to a Certificate of Compliance, which is independently signed off by a state or federal registered testing authority.

Placing the structural beams

6.5.7 Colorbond or zinc/aluminium sheeting

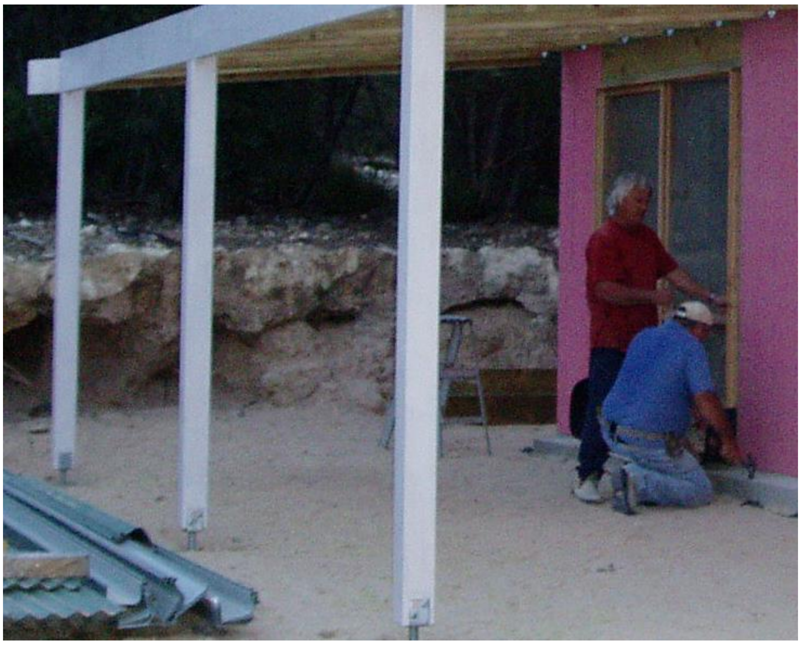
Metal cladding offers the advantages of economy and speed. Because the sheets of cladding are cut to accommodate the height or length of the wall they are covering, they can be rapidly clipped or screwed to provide a seamless wall.

The profiled sheets are maintenance free, substantially lighter than any other type of cladding material and offer a complete waterproof wall.

There is a hazard which can occur as a result of using dissimilar metals in close contact with the zinc/aluminium sheets.

The electrolytic action caused by the use of incompatible fastenings, flashings on lintels must be avoided. All fixing is to be carried out to manufacturer's specifications and to any special provisions as designated by local legislation and regulation.

Profiled zinc/aluminium sheeting must be fixed to a fair and flat wall surface and all fastenings or clips must be plumb, level and firmly embedded in the framework.



Fitting the door

Activity 22 - Wall cladding

Sketch the detail of a weatherboard clad frame building at the cill, head and side of a timber window.

Refer to BCA, Volume Two, Part 3.5.3.6.

Check your findings with the correct answer in the back of this Learner Resource under ‘Learning activity answers’.

* Retain this learning activity as part of your portfolio of evidence.

7. Windows and external doors

The installation of windows and external doors must comply with the relevant codes, manufacturer's specifications and accepted industry construction principles.

At each stage of the installation, the supervisor should check for conformance.

Doors and windows are fitted as per the window and door schedule. The schedule shows the profile and shape of the unit and the finished height and width of the frame. Window and door frames are usually dimensioned on the schedule by showing the height first.

When window and door frames are ordered, they are catalogued by number and may include a flyscreen specification.

Windows placed in the timber frame

7.1 Window types

Window frames can utilise many materials including steel, plastic, aluminium or composite.

Windows are usually glazed before delivery and are installed with all hardware such as locks, catches or similar furniture.

Whilst window sashes can be either opening or fixed, the common types include configurations including double hung, vertical or horizontal sliding, louvre, awning and casement.

All glazing requirements should comply with AS 1288 Glass in buildings – selection and installation and BCA, Volume Two, Part 3.6 and Part 3.8 (3.8.4 and 3.8.5 and 3.8.6).

7.2 Door types

Doors can be manufactured as panelled, glazed, solid and ledged and braced. Generally, most external doors combine solid construction with a degree of decorative panelling.

Interior doors are of flush panel construction and can be classified as either solid or hollow.

Door – window combination

7.2.1 Fitting of doors

Doors can be fitted as sliding or hinged, and if used externally, the door is fitted to a door frame, and for internal application, the door is fitted with a door jamb. As with the window frame, the external/internal frames or jambs can be manufactured in steel, aluminium, timber, plastic or composite.

Door frames can be fitted to steel openings in timber frames, or can be fitted to an opening in cavity brick, brick veneer or solid brick construction.

7.2.2 Fastenings

As metal frames and doors are susceptible to electrolytic action (electrolysis), care should be taken to avoid dissimilar metals when installing door units.

7.2.3 Weatherproofing

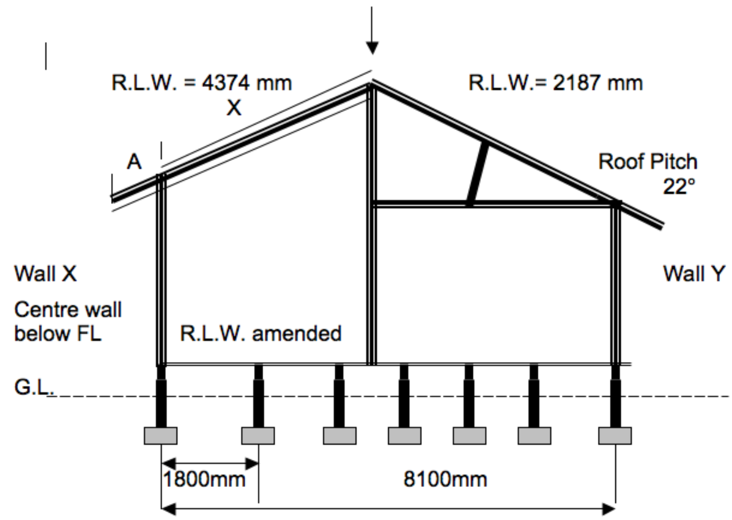
External doors are designed to be weatherproof and must be fitted to manufacturer's specifications and working drawing details.

Doors also form a major component in the thermal efficiency of the building shell.

(See BCA, Volume Two, Parts 3.12.3.3)

Activity 23 - Determining lintel size

Work out the F17 lintels for windows in walls 'X' and 'Y' to the given opening. (**Note:** All members to be single members.)



Determining lintel size

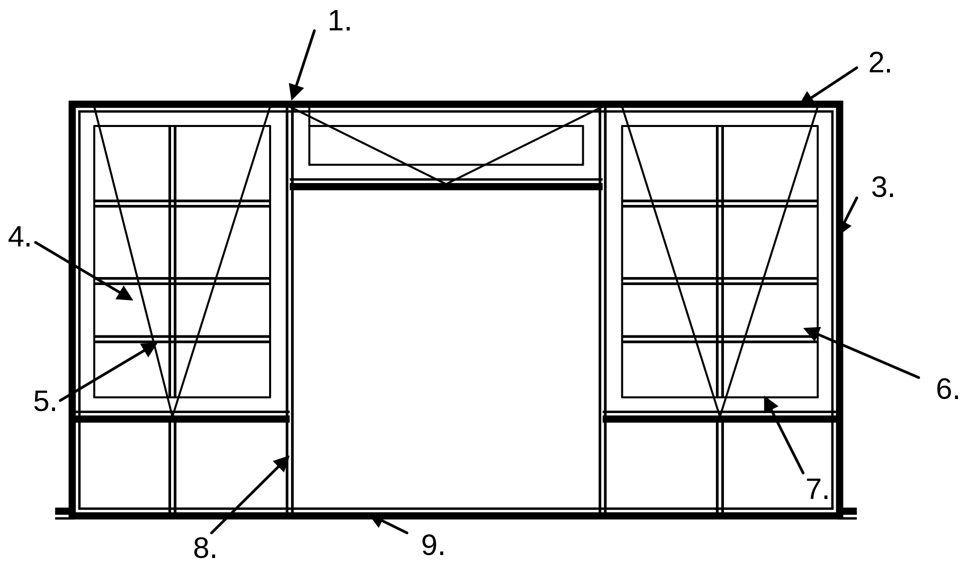
Opening size	Lintel size wall 'Y' Also table reference R.L.W. = X/2 + A Rafters @750 mm centres	Lintel size wall 'X' Also table reference
600 mm		
1500 mm		
2100 mm		
2400 mm		
2700 mm		
Truss roof (R.L.W. 5200) (900 mm Crs)		
2100 mm		
2700 mm		

Check your findings with the correct answer in the back of this Learner Resource under 'Learning activity answers'.

* Retain this learning activity as part of your portfolio of evidence.

Activity 24 - Identify window parts

In the sketch below, name the various parts of the window and also show the fixing positions to a timber frame.



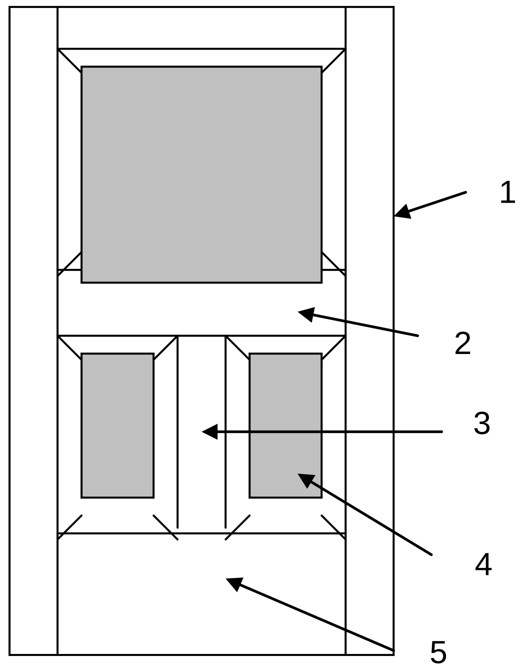
Identifying window parts

Check your findings with the correct answer in the back of this Learner Resource under 'Learning activity answers'.

* Retain this learning activity as part of your portfolio of evidence.

Activity 25 - Identify door parts

Name the various parts of the three panel door depicted below.



Identifying door parts

Check your findings with the correct answer in the back of this Learner Resource under 'Learning activity answers'.

* Retain this learning activity as part of your portfolio of evidence.

Learning activity answers

Your answers should include reference to the following key information. You may have included extra detail based on personal experience or further research into the topic however as a minimum the key information should be included in your answers.

If you are having difficulties with any of the learning activities you should contact your tutor for guidance.

Activity 1 – Consultation regarding structural integrity

He would alter the drawings to fit the new window opening as a sketch plan.

This sketch would then be forwarded to the structural engineer who would calculate the size of the beam over the window (lintel), and the supports at either end of the beam. These supports may be in the form of:

- jamb studs
- a timber post
- a steel column
- a brick column.

With this information, they would consult with the client, obtain his approval and then alter the set of drawings.

Activity 2 – Collecting and analysing project documents

- Slab layout
- The design of the slab drawn in section and to include details of the structural elements of the slab.
- The engineer's computations.
- The engineer's certification of his design drawings and computations.

Activity 3 – Assess new building technologies

Construct two stud walls from 90 x 45 mm F5 pine studs and plates, ensuring that the studs are opposite each other and at a maximum of 600 mm centres. Noggings are as for a normal wall.

Maintain a cavity width of 65 mm and build-in a vertical layer of 25 mm Boral Shaftliner Panel between the frames using H section studs cut 64 CH 55 metal studs at 600 mm centres, clipped at periphery to timber frames with aluminium clips.

Line the external faces of the stud walls with one layer of 10 mm Boral standard core or wet area plasterboard, applied either vertically or horizontally.

This wall is 265 mm wide and provides an FRL of 60/60/60 with a medium level of impact sound resistance.

Other systems are available from various manufacturers. This Boral wall system has a reference number of ATS24.

Activity 4 – Site investigation

Look at Toolbox BCGBC4007A for information on this matter.

Activity 5 – Site investigation research

1. To remove the grass and vegetation either to the whole site or to the immediate building area.
    - Site scrape
        - To excavate the site, cutting an area out of the site to form a ‘pad’ on which to build the house.
    - Cut and fill
        - This is the same as a site cut, however, the prepared pad for the house is not large enough and so on the downside of the cut location, the site is filled with soil raising this area up to the same as that of the cut level.
2. AS 1289 Methods of testing for engineering purposes and AS 3789 Guidelines on earthworks for commercial and residential developments.
3. Bearing capacity is the load which a soil or other supporting medium can safely carry without failure or unacceptably large settlement.
4. No. A foundation is the soil, subsoil or rock, whether built up or natural, upon which a structure is supported. A footing is the concrete structure that transfers the load from the structure to the foundation.
5. Through the ‘fill’ and into the natural ground at a depth where a foundation level has been investigated.
6. Levels

    Contour lines

    Type of material top soil and vegetation

    Measurements of boundaries

    Boundaries

7. M – moderately reactive clay or silt sites which can experience moderate ground movement from moisture changes.

   MD – Moderately reactive site, as above, with deep moisture changes.

8. As the tree grows, so does its roots extend, in most types of trees, to the edge of its canopy.

   For young trees, this often means that they grow under the house, and as they increase in size, can cause the footing to heave 'lift up'.

9. Brickwork may expand and contract due to thermal changes. Heavy clay soil will also move. The difference is called 'differential movement'.

10. Reactive soil – clay soil, for which a change in moisture content may result in a sufficient change in volume to affect the engineering performance of any structure in contact with the soil.

11. 100 kPa or for Classes A and S sites they may be founded on controlled sand fill in accordance with Clause 3.2.2.2 (a) of the BCA, Volume Two.

12. Class M means moderately reactive, whereas Class E determines an extremely reactive soil and so the footing will be required to go to a greater depth.

13. 50 mm in the first metre.

    a) An agricultural drain (Agi) set at least 600 mm at the base of the excavation with spoon drain or grated drain above it at surface level.

       Both being discharged to pits and led away from the building.

       For all cut sites, it is 'best practice' to construct a deep Agi drain some 1 to 2 metres back from the top of the cut – to cut off any water that may flow over the edge of the cut and down the excavation face.

    b) To a pit or pits – which would then be piped to the stormwater connection or to a distribution drain that was constructed throughout the property.

14. 1.5 times their mature height.

15. The recording of the soil structure throughout the length of the bore.

16. Take a sample of the soil at ground level – this is to see if it is a local or imported soil.

    With either a hand auger or mechanical auger drill down, in say 150 mm sections, and bring the soil to the surface and lay out on the ground in sequence.

    These samples are then bagged up, clearly marked, and taken away to a laboratory to be tested.

    Alternatively, the bore used takes a continuous core sample of the soil as it descends into the earth. This core sample is then taken away to the laboratory to be tested.

    This bore should be carried out to a depth of 1800 mm.

Activity 6 – Check footing specifications

1. Subfloor

   Stumps (see BCA, Volume Two, Part 3.2.5.6)

   - AS 2870 Stumps and footings – figure 3.6 and its respective table then go to Appendix E, figure E.2 which then refers you to figure E1.

     Note: This table is in the BCA, Volume Two, figure 3.2.5.2. There is a difference however, as the BCA only refers Classes A and S soil classifications, whereas the standard covers Classes A to H.
   - Ds is the depth of the stump pad from ground level – looking at in AS 2870 figure 3.6, we can see that Ds varies in depth with the classification of the soil as well as the type of building structure.
   - Stump pad size is indicated in AS 2870 Appendix E, figure E1.
   - Backfill – stumps must be embedded into the foundation material not less than 30% of their height above the ground level or 450 mm, whichever is the greatest.
   - Stumps must be braced:
     - by a full perimeter brace
     - for concrete stumps in accordance with AS 3600
     - for steel stumps in accordance with AS 4100
     - for timber stumps in accordance with AS 1684 – Parts 2, 3 and 4.

2. Bearers are generally spaced at centres that optimises the span/size of the floor joist, and to ensure that a solid floor base is achieved.

   The term spacing is more commonly known as centres (crs).

3. The BCA, Volume Two, Part 1.1.1.2 – DPC means a continuous layer of impervious material placed in a masonry wall or pier, or between a wall or pier and a floor, to prevent the upward or downward migration of water.

4. One of a series of parallel beams, spaced at regular intervals (spacing/centres) and spanning between walls, over the bearers, to which the flooring is fixed.

5. The means of construction and the components used form part of a system ie bearers, joists and flooring materials, and are largely, or completely, determined during the design of the project.

6. Any type of construction in which the building is supported by a structural frame of beams and columns rather than loadbearing walls, such as in steel framed construction, reinforced concrete framed construction or timber framed construction.

7. A non-load bearing covering to a structure, which typically provides protection from the elements.

Activity 7 – Flooring systems

Subfloor

1. Concrete has no predators which is readily available.

   Steel when exposed should be hot dipped galvanised, especially when close to the sea – has tensile strength for long lengths.

   Timber of a durability and/or preservative treatment that shall be appropriate for the expected service conditions. For example, red gum or cypress pine which is readily available, easy to work with.

2a) A strong horizontal plate, used mainly in temporary construction, which is laid on the ground to distribute the load from posts, stumps, or framing.

   Sloping support plate for raking shores, laid at a right angle to the line of thrust and usually supported on a timber base.

   A fixed or adjustable plate, that distributes the load from a load bearing member to the supporting structure – eg a timber stump.

b) Face to face distance between points capable of giving full support to a structural member between two points.

c) Face to face distance between points capable of giving full support to a structural member passing over at least three points of support.

d) AS 1684.4 provides building practice and procedures that assist in the correct specification and determination of timber members, bracings and connections. Member span tables are given in Appendix A of the Australian Standard.

Bearers

1. The span, or size, of the floor joist chosen to use in the construction of the subfloor system.

2. Bearers, if single members, are joined over the stump using one of the methods illustrated in Section 4.2.1 of AS 1684.4.

   Common methods for single members are butt joint, half check or scarfed joints.

   Single members used in subfloor construction are generally unseasoned timbers.

   Seasoned timbers used in subfloor construction are usually two members of a selected timber laminated together.

   Using this method of construction, the two members are laminated together and are continuous over the stumps supporting them, and are constructed to go from external wall to external wall.

3. The bearer has a hole drilled down through which the rod, built into the stump, is passed through, and the rod bent sideways over the bearer.

4. The bearers are carried on the external stump or on the engaged brick pier constructed within the base walling and seated on ant cap with a sheet of damp proof course under the bearer.

Floor joists

1. From Table A8, floor joists shown in AS 1684.4, we see that they are commonly installed at either 450 or 600 mm centres.

   The spacing of the joists is determined by the span of the flooring. This is determined by its thickness and quality/grade.

2. The floor joist has to seat the full width of the bearer.

   A pair of joists will be laid under each wall that is parallel to the direction of the joists.

Flooring

1. Australian hardwoods

   Cypress pine

   Radiata pine

   Plywood sheeting

   Particleboard sheeting

2. A platform floor is laid continuous over the floor joists and then the walls are constructed upon it.

   A fitted floor is laid over the floor joists in between the wall frames.

3. A material that complies with AS/NZS 2904.

   Embossed black polythene film of high impact resistance and low slip, with a nominal thickness of 0.5 mm prior to embossing, and meeting the requirements of Clause 7.6 of AS/NZS 2904.

   Polyethylene coated metal, that has an aluminium core of not less than 0.1 mm thick, is coated both sides with bitumen adhesive enclosed in polyethylene film of not less than 0.1 mm thick on each face, and has a nominal total thickness of not less than 0.5 mm prior to embossing.

   Bitumen impregnated materials of not less than 2.5 mm thickness, that meet the requirements of clause 7.5 of AS/NZS 2904, when used in walls which are not higher than 7.8 metres above the level of the DPC.

   Termite shields (with no penetrations) continuous through the wall or pier.

Activity 8 – Subfloor layout

Check your stump, bearer and floor joist layout drawings against the specifications which require:

- All walls are load bearing
- Bearers are 100 x 75 f8 @ 1800 centres
- Floor joists are 100 x 50 f8 @ 450 centres
- Stumps are type 2 footing
- Soil classification is Class S

If you are having difficulty, please contact your tutor.

Activity 9 – Specification requirements

1a) BCA, Volume Two, Part 3.2.3 refers to AS 3600. Concrete must have a strength at 28 days of not less than 20 MPa.

b) BCA, Volume Two, Part 3.2.5.3 (a) details the minimum thickness as 100 mm. Figure 3.2.5.5 states in note 5 that the slab thickness can be reduced to 85 mm in Western Australia around Perth and other locations, where the site consists of stable sands where specified by a professional engineer.

c) Minimum 150 mm – AS 2870, Section 5.3.4 (e).

d) BCA, Volume Two, Part 3.2.3.2 (d). The minimum cover for reinforcement to unprotected ground is 40 mm with an external exposure of 40 mm minimum.

e) BCA, Volume Two, Part 3.2.3.2 (d). 30 mm if the beam is protected.

f) BCA, Volume Two, Part 3.2.3.2 (d).

40 mm to unprotected ground

30 mm to protected ground

20 mm to internal surface

40 mm to external exposure

2a) 3 = Number of bard

L = Longitudinal

11 = Diameter of main bars

TM = Trench mesh

b) S = Square

L = Longitudinal

8 = 8 mm diameter

2 = 200 mm spacings

Activity 10 – Footing specifications

1a) Depth: 500 mm

Width: 300 mm

REO: 3-L12TM

Depth: 400 mm AS 2870, Section 3.2, figure 3.1

Width: 300 mm

Height of slab above ground line: 150 mm

AS 2870, Section 3.2, figure 3.6

Depth: 500 mm

Width: 300 mm

100 x 100 up to 1800 mm long BCA, Volume Two, Part 3.2.5.2

300 x 300 x 150 mm OR

Non-termite area 150 mm

Termite area 400 mm

AS 2870, Section 3.2, figure 3.6

1b) Minimum size of a strip footing:

Depth: 500 mm

Width: 300 mm

REO: 3-L12TM

AS 2870, Section 3.2, figure 3.6

Minimum size slab edge beam:

Depth: 400 mm

Width: 300 mm

Height of slab above ground line: 150 mm

AS 2870, Section 3.2, figure 3.1

2a) Suspended floor systems for a brick veneer dwelling. Not sure where this is coming from:

Class 'M' footing size:

Depth: 500 mm

Width: 300 mm

AS 2870, figure 3.6

2b) Concrete stump size:

100 x 100 up to 1800 mm long

BCA 2010, Volume Two, Part 3.2.5.2

2c) Type 2 concrete pad size:

300 x 300 x 150 mm

350 mm dia x 150 mm deep

AS 1684.4, Section 3.1

2d) Height of the bearer above ground line for a platform floor:

Non-termite area: 150 mm

Termite area: 400 mm

BCA 2010, Volume Two, Part 3.4.1, Table 3.4.1.2

Activity 11 – Suspended floor systems

1. 100 x 38 mm

   Note: Alterations details to drawing plus roof, centre wall need fixing.

2. I assume that A is marked directly under the wall or structure under the ridge.

   A row of stumps is always placed under the wall from which the roof ridge is going to be propped off.

   The stumps and the bearer can be offset from the wall 1.5 D (where D = the depth of the floor joist) – Refer to AS 1684.4 Clause 4.3.3.3.

3. 19 mm Radiata pine AS 1684.4 Table 5.3.

Activity 12 – Residential slabs

BCA, Volume Two, Part 3.3.4 and figure 3.3.4.1.

Activity 13 – Slab specifications

1. BCA, Volume Two, Part 3.1.2.3 (b)

   100 mm above finished ground level in low rainfall areas of sandy well drained soil

   50 mm above impermeable (paved or concreted areas) that slope away from the building in accordance with (a)

   150 mm in any other case

2. The appropriate slab height above finished ground level and the slope of the external finished surface surrounding the slab may vary depending on:

   - The local plumbing requirements, in particular, the height of the overflow relief gully relative to drainage fittings and ground level (to work effectively, they must be a minimum of 150 mm below the lowest sanitary fitting).
   - The run off for storms, particularly in areas of high rainfall intensity, and the local topography.
   - The effect of excavation on a cut and fill site.
   - The possibility of flooding.
   - The termite barrier provisions.

   Reference: BCA, Volume Two, Part 3.1.2.3 (b).

3. BCA, Volume Two, Part 3.2.3.2 (d)

   - 40 mm to unprotected ground
   - 30 mm to a membrane in contact with the ground
   - 20 mm to an internal surface
   - 40 mm to external exposure

4. A layer of material or component intended to restrict the transmission of water vapour.

5. A vapour barrier must be:

   - 0.2 mm nominal thickness polyethylene film
   - medium impact resistant – determined in accordance with criteria specified in clause 5.3.3.2 © of AS 2870
   - be branded continuously AS 2870 Concrete underlay, 0.2 mm medium impact resistant.

6. 20 mm, BCA, Volume Two, Part 3.2.2.7.
7. 10 mm, Refer to standards and tolerances.
8. 150 mm, AS 2870, figure 5.2

Activity 14 – Laying the floor system

Make sure that your sketch of the subfloor contains the following information:

- Foundation (Df)
- Footing
- Engaged piers
- Isolated stumps
- Bearers and joists for both termite and non-termite areas

Your sketch must relate to a building that meets the following specifications:

- Class ‘M’ soil
- Articulated BV construction
- Tiled roof on a conventional roof frame
- MGP12 Pinus framing

Send your sketch to your tutor for comment. If you have any questions please contact your tutor.

Activity 15 – Bracing requirements

You should have used the floor plan to indicate two directions of where the wind might come from towards the house.

You should have used the process from AS 1684.4, Part 8.3.2.2 and 8.3.2.3 to determine wind bracing and the bracing requirements for that house. You should have also referred to 8.3.2.4 and .5 before using Table 8.3 to select and then place your selected type of bracing, ie the number of units required.

As you are locating the bracing, you should have referred to Part 8.3.2.6 and Table 8.4 for rules relating to the distribution of bracing.

If you have any questions please contact your tutor.

Activity 16 – Structural timber members

Send your design of the timber members to your tutor for comment. If you have any questions please contact your tutor.

Activity 17 – Frame quality

Make sure that your sketch of the design shows the various opening widths and two wall frames from F8 OBHW and MGP12 Pine.

Your sketch should also include a door width 1200 mm wide and a window with an opening size of 2700 mm.

Send your design to your tutor for comment. If you have any questions please contact your tutor.

Activity 18 – Waterproof membrane

Make sure that your sketch of the bath hob shows where it returns down to a polymarble shower base.

Your sketch should also show all framing members, the wall lining, the selected wall finish, all flashings and sealants.

Send your design to your tutor for comment. If you have any questions please contact your tutor.

Activity 19 – Allowances for relevant services

Your tutor will provide you with a response to your specific solution. You must make allowances for electrical, plumbing, smoke detection, ducted heating and cooling, exhaust fans and communication systems.

Activity 20 – Truss calculations

1. 190 x 45, AS 1684.4, Table A35.
2. Please fix up rafter it should be continuous. 90 x 45 @ 900 crs – assumed metal roof.

Activity 21 – Bracing

Your answer should include discussion about diagonal bracing being used to prevent racking or movement of the frame.

Racking is the term used to describe the situation when the frame leans to one side.

Activity 22 – Wall cladding

Make sure that your sketch shows the detail of a weatherboard clad frame building at the sill, head and side of a timber window.

To assist in this activity you should have referred to the BCA, Volume Two, Part 3.5.3.6.

Send your design to your tutor for comment. If you have any questions please contact your tutor.

Activity 23 – Determining lintel size

Opening size	Lintel size wall 'Y' Also table reference R.L.W.= X/2 + A Rafters @750 mm centres	Lintel size wall 'x' Also table reference
600 mm	90 x 35	90 x 35
1500 mm	2 / 90 x 35	2 / 90 x 35
2100 mm	2 / 120 x 35	2 / 120 x 35
2400 mm	2 / 120 x 45	2 / 120 x 45
2700 mm	2 / 170 x 35	2 / 170 x 35
Truss roof (R.L.W. 5200) (900 mm crs)	No answer for truss roof	
2100 mm	2 / 120 x 35	
2700 mm	2 / 170 x 35	

Activity 24 – Identify window parts

1. Reveal
2. Window head
3. Jamb
4. Glass
5. Glazing bars
6. Awning sash
7. Colonial frame
8. Mullion
9. Cill

Activity 25 – Identify door parts

1. Site
2. Mid rail
3. Centre rail
4. Feature panel
5. Bottom panel

Appendices

Appendix 1 – Employability Skills

The following table shows the Employability Skills embedded within this unit together with the appropriate assessment task that assess these skills. Note that not all the Employability Skills in the qualification are assessed in this unit. Assessments for other units will cover the remaining Employability Skills.

Employability Skills	Evidenced by	Assessment task
Communication	Oral and written communication skills that contribute to productive and harmonious working relations between co-workers, customers and other stakeholders	Task 1 Task 2 Task 3 Task 4 Task 5 Task 6
Teamwork	Skills that through cooperation and collaboration contribute to productive working relationships with others to achieve the desired outcomes of the project	N/A
Problem solving	Appropriate analytical skills that contribute to timely completion of tasks and productive outcomes	Task 1 Task 2 Task 3 Task 4 Task 5 Task 6
Initiative and enterprise	Skills that contribute to innovative outcomes, within scope of responsibility	Task 1 Task 2 Task 3 Task 4 Task 5 Task 6
Planning and organising	Task management skills that support the attainment of project goals and objectives and the strategic planning of the organisation	Task 6
Self management	Skills to manage personal reactions to responsibilities and challenges in the workplace and contribute to self-satisfaction and growth	Task 6
Learning	Skills that contribute to ongoing professional development	Task 6
Technology	Skills that contribute to effective execution of tasks using a range of appropriate technological options and a willingness to embrace emerging technologies	Task 1 Task 2 Task 3 Task 4 Task 5 Task 6

Appendix 2 – Qualification structure

This Learner Resource, *CPCCBC4010B* forms part of the CPC50210 Diploma of Building and Construction (Building) qualification.

BSBOHS504B	Apply principles of OHS risk management
BSBPMG411A	Apply quality management techniques
(previously CPCCBC404A)	
BSBPMG505A	Manage project quality
(previously BSBPMG513A)	
BSBPMG508A	Manage project risk
(previously BSBPMG517A)	
BSBPMG522A	Manage projects
(previously BSBPMG510A)	
CPCCBC4001A	Apply building codes and standards to the construction process for low rise building projects
CPCCBC4003A	Select and prepare a construction contract
CPCCBC4004A	Identify and produce estimated costs for building and construction projects
CPCCBC4010A	Apply structural principles to residential low rise construction
CPCCBC4013A	Prepare and evaluate tender documentation
CPCCBC5001B	Apply building codes and standards to the construction process for medium rise building projects
CPCCBC5002A	Monitor costing systems on medium rise building and construction projects
CPCCBC5003A	Supervise the planning of on-site medium rise building or construction work
CPCCBC5007A	Administer the legal obligations of a building or construction contract
CPCCBC5008A	Apply structural principles to the construction of medium rise buildings
CPCCBC5009A	Identify services layout and connection methods to medium rise construction projects
CPCCBC5010A	Manage construction work
CPCCBC5011A	Manage environmental management practices and processes in building or construction
CPCCBC5018A	Apply structural principles to the construction of medium rise buildings

Appendix 3 – Unit of competency

CPCCBC4010A Apply structural principles to residential low rise constructions

Unit description

This unit of competency specifies the outcomes required to apply structural principles to the erection or demolition of low rise residential structures using conventional methods. The unit addresses those structures classified by the Building Code of Australia as Classes 1 and 10. Knowledge of the application of structural principles in accordance with Australian Standards is essential.

Employability skills

This unit contains employability skills.

Application of unit

This unit of competency supports the needs of builders, site managers, forepersons and other managers in the building and construction industry responsible for overseeing and managing the demolition or erection of structures.

Sector

Construction

Elements and Performance Criteria

ELEMENT	PERFORMANCE CRITERIA
1. Apply structural principles when planning the erection or demolition of a structure.	1.1. Main ***structural principles*** that apply to the erection or demolition of a ***residential low rise*** structure are identified. 1.2. Structural performance of a structure is described in terms of the effect of section properties on various materials. 1.3. Structural performance characteristics of slabs, floors, beams, columns and retaining walls are explained and applied to the planning of the construction work. 1.4. Demolition of existing structures is coordinated in accordance with legislative and planning requirements, environmental standards, and safe work practices.
2. Analyse and plan for the structural integrity of Class1 and Class 10 buildings.	2.1. Relevant ***industry professionals*** are consulted as required to provide advice regarding the design process and the structural integrity of the proposed Class 1 or Class 10 building. 2.2. ***Project documentation*** is collected and analysed to assist in the analysis of plans and specifications. 2.3. Project documentation is analysed for compliance with BCA requirements for bushfire, high wind, earthquake and alpine environments. 2.4. New and emerging building technologies are assessed for application to the construction process and their compliance with BCA requirements and Australian standards. 2.5. Pre-commencement site inspection is conducted to confirm analysis.
3. Plan, coordinate and manage the laying of footings.	3.1. Footings are set out in accordance with building's plan. 3.2. Structural integrity of the footings specified in building's plan is assessed for compliance with relevant codes and accepted industry construction principles. 3.3. ***Footings*** specified in building's plan are laid and checked for compliance with project documentation. 3.4. Damp coursing, provision of termite barriers, and other relevant techniques are planned, implemented and checked in accordance with codes, standards and industry practice.

ELEMENT	PERFORMANCE CRITERIA
4. Plan, coordinate and manage the laying of floor system.	4.1. Concrete slab or bearers and joists specified in building's plan are assessed for structural integrity and compliance with relevant codes and accepted industry construction principles. 4.2. Laying of ***floor system*** specified in building's plan is supervised and checked for compliance with project documentation.
5. Plan, coordinate and manage the building of structural and non-structural wall systems.	5.1. Technical construction principles and performance of ***materials*** used in the construction are identified and analysed in the planning of the building and construction project. 5.2. Application of bracing requirements, tie-downs, tolerances, allowances, and fixing and installation of components are planned, implemented and checked for compliance with relevant Australian standards, codes and manufacturer specifications. 5.3. Structural timber members are selected for low rise buildings to conform to AS1684 requirements. 5.4. Processes are put in place and managed to ensure quality of the frame, whether factory pre-cut and pre-nailed, factory pre-cut and assembled on site, or cut and assembled on site. 5.5. Vapour permeable sarking or a waterproof membrane, relevant to construction method, is attached and checked.
6. Plan, coordinate and manage the building of roof system.	6.1. Structural integrity of roof system components specified in building's plan is assessed for compliance with relevant codes and accepted industry construction principles. 6.2. Erection of roof trusses is planned, implemented and checked in accordance with requirements of building plan, ***type of roof*** being constructed, relevant codes and accepted industry construction principles. 6.3. Processes are put in place and managed to ensure quality of the manufactured roof trusses or hand-cut roof system. 6.4. Roof sarking and cladding are planned and installation is supervised and checked for compliance with codes, standards and industry practice.
7. Plan, coordinate and manage the external wall cladding of structure.	7.1. Structural performance of ***cladding*** to be used for bracing in the frame construction is assessed for compliance with relevant codes, manufacturer specifications and accepted industry construction principles.

ELEMENT	PERFORMANCE CRITERIA
	7.2. Installation of the cladding, as specified in building's plan, is supervised and checked for compliance with standards and accepted industry construction principles. 7.3. Installation of windows and external doors is supervised to ensure compliance with relevant codes, manufacturer specifications and accepted industry construction principles.

Required skills and knowledge

This section describes the skills and knowledge, and their level, essential for this unit.

Required skills

- Apply manufacturer's specifications and Australian Standards and codes
- Apply structural principles to a variety of structures within BCA Classes 1 and 10
- Communication skills to:
  - consult with industry professionals
  - enable clear and direct communication, using questioning to identify and confirm requirements, share information, listen and understand
  - read and interpret project documentation
  - use language and concepts appropriate to cultural differences
  - use and interpret non-verbal communication
- Identify and analyse relevant information
- Select structural members based on project or specification requirements
- Work safely to OHS regulations and site requirements

Required knowledge

- Building and construction industry contracts
- Relevant state or territory building and construction codes, standards and government regulations
- Underlying mathematics related to structural analysis
- Workplace safety requirements

Range Statement

The range statement relates to the unit of competency as a whole. It allows for different work environments and situations that may affect performance. ***Bold italicised*** wording in the performance criteria is detailed below. Add any essential operating conditions that may be present with training and assessment depending on the work situation, needs of the candidate, accessibility of the item, and local industry and regional contexts.

Structural principles include:	• behaviour of structural materials • loads and loading • performance of beams • performance of columns • performance of roof trusses • section properties • solution of force systems • wind bracing.
Residential low rise buildings as described within the BCA are:	• Class 1 • Class 10.
Industry professionals include:	• architects • draftspersons • engineers • quantity surveyors • surveyors.
Project documentation includes:	• building approval plans • contract plans • designs and specifications • engineer footing designs and specifications • original contour survey plan • registered plans • retaining walls • site plans • soil investigation reports • structural floor systems, wall systems and roof systems • tanking designs and specifications • underpinning, rock anchors and shoring designs and specifications.

Footings include:

- bored pier footings
- columns or stumps
- concrete slab floors
- piers and beams.

Floor system components of the bearers and joists include:

- compressed sheet wet area flooring
- engineered floor joists
- fitted (cut-in) floors
- platform floor construction
- sheet flooring
- tongue and groove flooring.

Materials include:

- cavity brick
- concrete block
- structural steel
- timber.

Type of roof includes:

- box gable
- dual pitch roof
- Dutch gable
- Dutch hip
- gable end
- hip and valley
- north light
- skillion.

Cladding used on timber frame constructions includes:

- brick veneer
- coatings over base materials
- colourbond or zincalume sheeting
- fibre cement or compressed wood panelling
- weatherboards.

Evidence Guide

The evidence guide provides advice on assessment and must be read in conjunction with the performance criteria, required skills and knowledge, the range statement and the Assessment Guidelines for this Training Package.

Overview of assessment	• This unit of competency could be assessed by the effective application of structural principles and concepts in accordance with the range of variables and application to only one sector of the building and construction industry. • This unit of competency can be assessed in the workplace or a close simulation of the workplace environment, provided that simulated or project-based assessment techniques fully replicate construction workplace conditions, materials, activities, responsibilities and procedures.
Critical aspects for assessment and evidence required to demonstrate competency in this unit	• A person who demonstrates competency in this unit must be able to provide evidence of the ability to: – assess the structural integrity of a variety of structures found on building and construction sites – apply the structural principles behind the safe erection and demolition of a low rise structure classified within the BCA as Classes 1 and 10 – apply technical construction principles to the appropriate selection, integration and building in of construction elements and components – coordinate, plan, implement and check the building of a low rise structure.
Context of and specific resources for assessment	• This competency is to be assessed using standard and authorised work practices, safety requirements and environmental constraints. • Assessment of essential underpinning knowledge will usually be conducted in an off-site context. • Assessment is to comply with relevant regulatory or Australian Standards' requirements. • Resource implications for assessment include: – documentation that should normally be available in either a building or construction office – relevant codes, standards and government regulations

- office equipment, including calculators, photocopiers and telephone systems computers with appropriate software to view 2-D CAD drawings, run costing programs and print copies technical reference library with current publications on measurement, design, building construction and manufacturer's product literature suitable work area appropriate to the construction process
- reasonable adjustments for people with disabilities must be made to assessment processes where required. This could include access to modified equipment and other physical resources, and the provision of appropriate assessment support.

Method of assessment

- Assessment methods must:
  - satisfy the endorsed Assessment Guidelines of the Construction, Plumbing and Services Integrated Framework Training Package
  - include direct observation of tasks in real or simulated work conditions, with questioning to confirm the ability to consistently identify and correctly interpret the essential underpinning knowledge required for practical application
  - reinforce the integration of employability skills with workplace tasks and job roles
  - confirm that competency is verified and able to be transferred to other circumstances and environments.
- Validity and sufficiency of evidence requires that:
  - competency will need to be demonstrated over a period of time reflecting the scope of the role and the practical requirements of the workplace
  - where the assessment is part of a structured learning experience the evidence collected must relate to a number of performances assessed at different points in time and separated by further learning and practice, with a decision on competency only taken at the point when the assessor has complete confidence in the person's demonstrated ability and applied knowledge

  - all assessment that is part of a structured learning experience must include a combination of direct, indirect and supplementary evidence.
- Assessment processes and techniques should as far as is practical take into account the language, literacy and numeracy capacity of the candidate in relation to the competency being assessed.
- Supplementary evidence of competency may be obtained from relevant authenticated documentation from third parties, such as existing supervisors, team leaders or specialist training staff.

References

- BuildRight Toolbox CD-ROM: See included in provided resources.
  - BCG03 General Construction Training Package
  - BCG40106 Certificate IV in Building and Construction (Building)
- Department of Climate Change and Energy Efficiency (2010) *Australia's guide to environmentally sustainable homes.*
- Ivanoff, V. (1986) *Engineering Mechanics*, McGraw-Hill Book Company
- Meriam, J. L. & Kraige, L.G. (1998) *Engineering Mechanics – Statics*, 4th edn, John Wiley & Sons Inc
- Wyatt, K.J. & Hough, R. (2003) *Principles of Structure*, 4th edn, UNSW Press