STRUCTURAL TIMBER ASSOCIATION
Building solutions in timber

Edinburgh Napier UNIVERSITY

citb

TIMBER FRAME WORKBOOKS

Design

KNOWLEDGE

LEARN

how timber frame is designed, manufactured and erected on site.

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1. Introduction and Welcome

1.1 The STA Design Training Programme

Welcome to your Knowledge Workbook.

The production of these workbooks has been **supported financially** by **The Construction Industry Training Board (CITB). The Structural Timber Association (STA)** is extremely grateful to them.

The Structural Timber Association, on behalf of the industry, has developed this training programme with CITB to provide recognition of the skills and competences of existing timber frame designers together with raising the skill levels of any unskilled or untrained timber frame designers to an acceptable level of competence.

The programme will also provide career paths for timber frame designers and assist young entrants to the timber frame industry. Over time the intention is to allow only those designers who are qualified to design timber frame buildings.

A structured training programme has been devised at three levels:

- Design
- Manufacture
- Erection

Each of the three levels is split in to three modules:

- Health and Safety
- Knowledge
- Practical Skills

For most of us, our home is our largest expense and we expect it to be built to the highest standards by well trained and suitably qualified people. By using these workbooks, we, as an industry, can now provide you with the opportunity to achieve this goal. Also by having a qualified workforce we can compete with the rest in quality and workmanship.

We hope you enjoy working through this workbook. Please add to it in any way you wish. We look forward to awarding you with your Timber Frame Competency Award qualifications in the near future.

Andrew J. Carpenter

Andrew Carpenter,
Chief Executive, STA.

Education and training. STA/CITB.

If you have any queries or require any further information regarding this booklet seek advice within your own company. You may also contact:

Structural Timber Association

The e-Centre

Cooperage Way Business Village

Alloa

FK10 3LY

United Kingdom

Tel: 01259 272140

Fax: 01259 272141

Email: **office@structuraltimber.co.uk**

If you have any general enquiries on any other education and training matter, again either seek advice within your company, or visit

goconstruct.org

STRUCTURAL TIMBER ASSOCIATION

Building offsite solutions in timber

2. Aims and Objectives

2.1 Target audience

The Design workbook series is aimed at timber frame fabrication designers.

The designers may be based at a timber frame business for the practical part of their training. The workbooks are applicable to designers based at consultancy support businesses and these designers will need to partner with a manufacturer to undertake a factory practical exercise.

The key responsibilities of the timber frame designers are expected, but not limited, to be designing and specifying the timber frame components in accordance with the architects' drawings and the timber frame manufacturing system. For this reason, this workbook includes topics relevant to manufacturing and building design, to ensure the timber frame fabrication designer is aware of the context of their work.

This workbook should be combined with practical application in a timber frame business, including training and support. The learners are encouraged to discuss the topics covered in the workbooks with their colleagues and supervisors.

2.2 Knowledge

Welcome to the Knowledge workbook.

This Knowledge workbook looks at the background knowledge you need to have and understand in order to become an essential member of your team.

The aim is to give you the necessary knowledge so that it will help you to develop your all-round skills and understanding by guiding you through the topics to be a timber frame designer.

2.3 What is in this workbook

This workbook is divided into sections. Please refer to the Contents page for an overview of the sections which are covered in this workbook.

Each section follows a similar pattern:

- you will be given the information to read that explains what you will be required to do, followed by some exercises to complete
- where you see a white activity box (example given below), this will indicate that there is a task for you to do. If you can't fit your answers in the space provided, please use a separate sheet
- the activities are designed to help you find out about different topics within the workbook
- at the end of each section there are some questions for you to

answer. These are designed to check your understanding and to identify any areas that you may need to brush up on

- the workbooks have been designed to be enjoyable as well as informative
- on completion of this course you will gain suitable recognition that employers now expect

2.4 What qualifications can be obtained

The training programme consists of 3 levels:

- Design
- Manufacture
- Erection

Each level of the programme has 3 modules as shown below – each of the levels follow the same structure:

- Health and Safety
- Knowledge
- Practical Skills

Please note:

- this workbook does not replace your own company's documents and/or the main contractor's site rules
- furthermore, it supports the small handbook titled: A Pocket Guide to Timber Frame Construction.

Activity

Take a moment to reflect on the knowledge you would like to gain from this workbook and how it will be useful for your career. Write these points down, they will serve as a motivation reminder throughout your work.

3. From the forest to the wood

3.1 Overview

Wood and wood products are all around us.

Wood (timber) is used for construction, joinery, furniture and toys while paper provides our stationery, books, newsprint, magazines, packaging, toilet paper and a host of other products.

From the ceiling and flooring of the building to the packaging of our breakfast cereal, wood is an integral part of our daily lives and every person in the UK consumes approximately one tonne of wood every year.

Over the last 20 years the timber industry has grown rapidly, this was mainly due to major investments in processing capacity. UK forestry industry is currently employing some 167,000 people and providing over £7billion to GDP.

Currently the UK can provide only a small percentage of timber required by industry and population size; hence it largely depends on import of this product. According to the Forestry Statistics 2015 imports accounted for 81% of all wood in the UK in 2014.

Growing trees is a long-term business, the trees used for structural timber mature over many decades, but timber from Scandinavia, The Baltics and Canada as well as the UK and elsewhere is managed and extracted under environmentally sound principles.

Where timber production is the main objective, today's professional foresters aim to integrate the growing and supply of a raw material for industry with the creation and enhancement of the landscape and the environment.

This balance provides a habitat for animal, plant and insect life, and where possible, an area of recreation for the public.

Activity

Give some examples of timber products

3.2 Structure of timber

Wood is a natural, heterogeneous, anisotropic, hygroscopic composite material. Its structural properties are highly variable as a result of a range of influencing factors. Consideration must be given to the level of effect the influencing factors have in relation to the structural properties of the timber section.

The main features of a tree's trunk include:

- outer and inner bark
- growing layer, a growth centre of the tree. New wood cells are formed over the old wood and bark cells are formed on the outside
- sapwood, a lighter coloured ring outside the heartwood. It conducts water from the roots to the leaves. Has a low resistance to fungal or insect attack, but it can be easily treated due to high permeability
- heartwood, darker coloured area in the centre. Its function is to provide the mechanical support of the tree. The resistance to fungal or insects attack varies depending on the species. It has a lower permeability than sapwood and is harder to treat.

3.3 Moisture in timber

Moisture content is the amount of moisture in the timber or wood-based products and is expressed as a percentage of its dry weight.

Water is present in timber both in form of free water in the cell cavities or water bound in the cell walls.

As the timber dries, first the free water is removed until the fibre saturation point is reached at approximately 27% moisture content. Beyond this the water held in the cell walls is removed and the timber starts to shrink.

The equilibrium moisture content

It is important to have an appreciation and understanding of some of the main factors which affect the strength of timber:

- Density
- Natural defects
- Direction of slope and grain
- Moisture content
- Biological degrade

is the point at which the timber or wood-based product neither gains nor loses moisture when exposed to a constant condition of temperature and humidity.

Once the tree is cut its moisture content falls to approximately 27% - this state is referred to as fibre saturation point. Until this point wood remains dimensionally stable. Before timber goes on the market it has to be dried (seasoned), this process can remove up to a third of moisture from the cells.

Once this process is complete, timber is referred to as seasoned and its moisture content vary between 12 and 25% depending upon end use For example moisture content in timber used as framing material in heated houses and separated from external environment is generally low (between 12 and 14%), whereas if timber is exposed to humid conditions, like bridge decks, its moisture content will be significantly higher (between 20 and 25%). In general, solid timber is typically installed at around 15-18% moisture content, and should be no greater than 20%, but reduces down to around 10% in a heated building in service.

Strength grade markings will indicate the condition of the wood supplied so you must take the appropriate action to ensure it remains in such condition by careful storage, handling, transport etc.

Moisture content of timber on site, in the yard or in buildings is generally measured using a moisture meter as this is the easiest method.

Moisture meters typically measure electrical resistance or capacitance which is converted to a corresponding moisture content value.

Note that a moisture meter gives an indication of the timber's moisture content only i.e. it provides a reliable estimate. In order to accurately measure the moisture content of timber its mass should be measured in both a wet (in service) and dry (oven or similar) condition and its moisture content (%) determined by dividing the difference between wet mass and dry mass (wet mass - dry mass) by the wet mass then multiplying the result by 100.

$$\text{MC (\%)} = \frac{\text{(wet mass - dry mass)}}{\text{wet mass}} * 100$$

3.4 Dimensional changes

Wood is dimensionally unstable below its fibre saturation point: it swells as it gains moisture and shrinks when loses moisture. Changes are more likely to occur in the direction of the growth rings (tangentially) and about half as much across the rings (radially). Dimensional changes in the length are virtually nil. Changes in dimension timber may result in warping or splitting of wood, see pictures below. The degree of movement varies between different species of timber and for some uses can be a significant factor in the choice of timber.

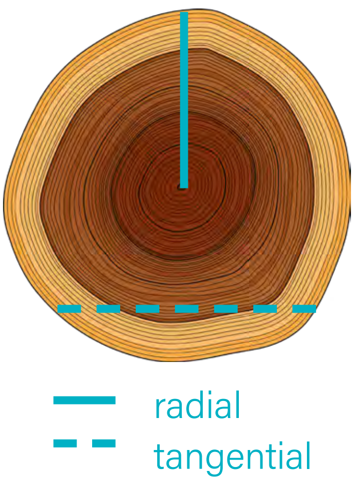
3.5 Green issues

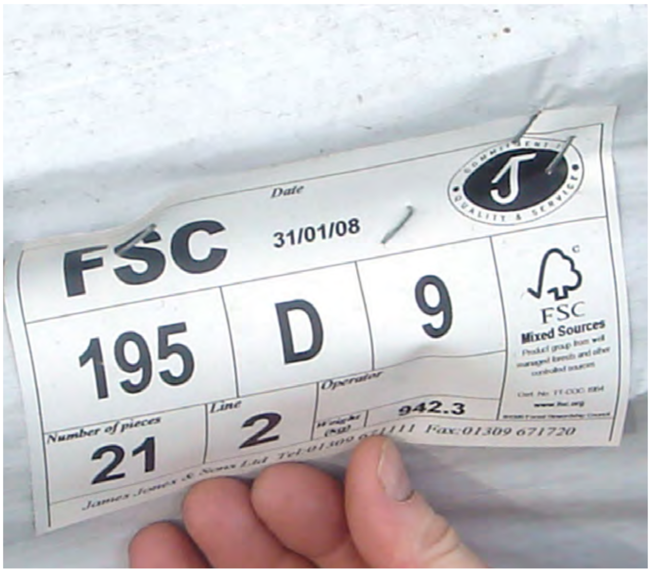
With ever-growing concern for the environment and global warming, it is in everyone's interests to keep energy demands as low as possible.

Building energy efficient, well-insulated homes to reduce fuel consumption and running costs is essential.

However, what people working in the built environment do not realise is that even before a house

Timber treated with water-borne preservatives must be re-dried to appropriate moisture content after treatment.

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is built, the materials used in its construction have an embodied energy, which refers to the energy consumed by all of the processes associated with the construction of a building. The process includes mining and processing of natural resources as well as manufacturing, transport and assembly of a building product.

Timber has a big advantage here as it is produced by natural means - sun, water and air. Moreover, during its years of growth timber sequesters carbon and requires little energy for manufacture and at the end of its life it has inherent energy which can be released by combustion.

The chart below highlights the advantages of timber by comparing the energy content per square metre of construction using different wall systems commonly used in the house building industry.

Most figures quoted for embodied energy are based on the Process Energy Requirement (PER), which is a measure of the energy directly related to manufacture of the material only.

For example, a timber frame wall in a typical three bedroom detached family house has a PER of around 7,450kWh, while a concrete block wall in the same property requires 1.7 times more energy, with a PER of around 12,816 kWh.

Timber is also the only renewable structural building material available, and the majority of timber frame package companies invest heavily in well managed replanting programmes.

3.6 Timber supply chain and products

The majority of timber used across the timber frame industry in the UK is softwoods from the Baltic States and from Canada. Some of the resource is home grown, UK timber. As a rule, all timber suppliers source their materials from renewable resources and expertly managed forests.

In order to comply with the relevant regulations and requirements timber used structurally is comprehensively treated against insect attack and general decay.

There are several key stages involved in the supply chain which, in effect, cover the processes from the forest to the finished building:

- **Forestry:** softwood is only taken from managed and sustainable forests
- **Milling:** timber is debarked and passed through the sawmills
- **Treatment:** timber is usually treated using a suitable preservative
- **Architecture:** an architect designs the building or previous architectural designs are used
- **Engineering:** the forces on the building are calculated, the arrangement and materials are specified by an engineer
- **Timber frame (fabrication) design:** the architectural design is passed to the timber frame business in-house fabrication designers to design the timber frame kit. May also be referred to as fabrication designers.
- **Timber frame engineering:** the forces on the frame are calculated, the components and connections are specified by an timber frame engineer
- **Timber frame manufacture:** the manufacturers produce the elements as specified by the in-house fabrication designers
- **Private and public sector house builders & housing associations:** are customers

Some key facts and figures:

- the majority of sawn softwood comes from Sweden (44%), Latvia (15%) and Finland (13%)
- particleboard imports to the UK comes from France (24%), Germany (21%), Ireland (13%) and Belgium (11%)
- the largest single source of sawn hardwood imports to the UK is the USA (21%)

Activity

Find out the origin of the majority of the timber that your company uses

targeted by the timber frame companies

- **Construction companies:** these are customers and are kept informed of timber frame benefits and advantages
- **Site erection:** the final stage where everything comes together: after the foundations and sole plates, the timber kit is erected, the subsequent trades complete the roof, exterior and the interior of the building.

3.7 Engineered wood products

Engineered wood products (EWP) are products manufactured from timber strips, chips, strands, particles, veneers and/or fibres which are mechanically bonded together using adhesive or other fixing methods in order to create durable composite materials typically for structural applications.

EWP is widely used in timber frame construction and potentially offers the following benefits:

- enhanced structural performance
- increased dimensions
- greater spans and scope of application
- ease of installation
- ease of lifting and handling
- improved structural and dimensional consistency
- reduction in moisture content
- reduction in waste/reuse of waste for production

Some examples of the most commonly available and widely utilised EWP are described in the following sub-sections.

3.7.1 Cross Laminated Timber (CLT)

CLT is produced from timber strips glued in perpendicular layers under high pressure, either mechanically pressed or in a vacuum bag to form a planar product. Previously, offcuts and lower grade timber was used in the production of CLT however now strength-grated timber is used to produce lamellas for CLT. In the factory the cross-laminated solid timber panels can be cut to the required shape and size. Further to this, routing and holes for services and connections can easily be incorporated within the panels as required.

Panels are shipped to site and assembled rapidly with metal fasteners. CLT shares similar attributes with Glulam but is manufactured in slab form. Although Glulam may form the supporting elements CLT has its own internal capacity and can provide self-supporting walls, roof and floor slabs with the potential for long spans and high rise construction. In addition to this there are opportunities for bridge and hybrid type construction.

Typical applications: core structural elements, framing, floor, wall and roof elements.

3.7.2 Other varieties of CLT

Nailed CLT (NCLT) is a panel product that is manufactured with alternating thin lamellas, not unlike CLT, in multiple layers, fastened using nails rather than bonded with adhesive.

Typical applications: primarily used for wall elements in low to medium-rise residential and commercial construction.

Interlocking CLT (ICLT) is a cross laminated product, utilising no glues and no fasteners. Dovetail notches interface with a nested key to create multi-cross-laminated panels that range from 3-7 layers. ICLT is labour intensive to produce, but requires little investment for start-up. Layers are cut with traditional CNC routers, assembled by hand and then pressed with a mobile hydraulic press.

Typical applications: primarily used for wall elements in low to medium-rise residential and commercial construction.

3.7.3 Nail Laminated Timber (NLT)

NLT is a planar-stacked lamella or plank product connected with steel or aluminium shank nails or screws fastening the planks together crosswise. NLT is suitable for roof and floor elements of limited span but requires racking sheathing to produce lateral resistance if to be used as a wall element and therefore is more suitable for use in low to medium-rise residential and commercial construction.

Typical applications: floor, wall and roof elements.

3.7.4 Dowel Laminated Timber (DLT)

DLT, often referred to as 'Brettstapel,' is a product that is fabricated from softwood timber lamellas stacked in one plane and connected with hardwood timber dowels at regular centres. This relatively simple method of construction has the potential to utilise lower grade timber which would otherwise be unsuitable for use in construction, to form load-bearing solid timber wall, floor and roof panels. The fixation between the planks is achieved by inserting hardwood dowels with a moisture content lower than the lamellas into regularly spaced pre-drilled holes that run perpendicularly to the lamellas; over time the dowels expand to achieve moisture equilibrium thus 'locking' the lamellas together and creating a structural load-bearing system.

Typical applications: floor, wall and roof elements for low to medium-rise residential and commercial construction.

3.7.5 Glued Laminated Timber (Glulam/GLT)

Glulam comprises a number of layers of dimensioned timber bonded together with structural adhesive to increase structural performance. By laminating a number of smaller timber elements a single larger strong structural member is manufactured. GLT is primarily used as post or beam heavy timber framing elements, as well as curved and arched structural shapes. Glulam is used in conjunction with CLT and other solid timber products in building projects ranging in size and type servicing residential and commercial construction alike.

Typical applications: straight and curved beams and columns (supporting elements), post and beam, portal systems, roof and bridge structural elements.

3.7.6 Laminated Veneer Lumber (LVL)

LVL is a timber composite made with laminated wood veneer. LVL is manufactured from thin peeled veneers of wood typically 3mm thick, glued with structural adhesive. Generally, the grain runs parallel to the main axis of the member; however veneers may also be included that run perpendicular to the axis of the member (cross-banding).

Typical applications: beams, joists, columns, rim boards.

3.7.7 I-joists

An I-joist is a composite engineered timber joist of a similar cross section profile to steel I-beams and typically comprises solid timber or Engineered Wood Product (EWP), most typically laminated veneer lumber (LVL), top and bottom flanges bonded in parallel to a web of wood panel material such as OSB or hardboard though I-joists with corrugated steel, LVL or solid timber webs are available yet less common. The web is typically inserted in to routed grooves in both flanges and glued though the flanges may be affixed to either side of the web with adhesive and/or mechanical fasteners (2 part flange) although this is much less common. I-joists work on the principle that the flanges carry the bending moment and axial forces and the web carries the shear forces.

Typical applications: core components (joists, studs and rafters) for floor, wall and roof elements for domestic, commercial and industrial applications.

3.7.8 Open web beams

A composite engineered joist typically comprises solid timber top and bottom chords plated together in parallel with punched metal webs pressed in to the chords, though variations of open web beams with timber webs plated to the top and bottom chords or similar are available.

Open web beams are typically used as joists, studs and rafters for floor, wall and roof applications. Open web beams can be used for domestic, commercial and industrial applications.

Open web beams can be produced using truss design principles and construction methods.

Typical applications: core components (joists, studs and rafters) for floor, wall and roof elements for domestic, commercial and industrial applications.

3.7.9 Box beams

Box beams are of a similar form to I-joists but with a web affixed to both external faces of the flange using adhesive and/or mechanical fasteners to create a hollow 'box' section. Box beams typically comprise solid timber or LVL flanges and OSB or hardboard webs though there are many variations and the configuration and materials used will largely be dependent upon the application and design requirements.

Typical applications: core components (joists, studs and rafters) for floor, wall and roof elements for domestic, commercial and industrial applications. Columns, beams, posts.

3.7.10 Structural Insulated Panels (SIPs)

SIPs are prefabricated panels which are suitable for use in domestic and commercial structures.

They are formed using a core of rigid insulation adhesively bonded between two sheathing elements. The rigid foam is commonly expanded or extruded polystyrene or urethane but can be other products. Plywood or OSB/3 is standard for the sheathing materials though MgO or similar may be used where enhanced fire performance is required.

Sheathing boards are adhesively bonded to rigid foam core. Rebates are left in the core material to accommodate connection details, typically splice connections.

Openings should be designed for during construction with panels fabricated to allow a frame to be incorporated into the panels where necessary.

SIPs panels offer thermal and structural performance due to the nature of construction.

Typical applications: wall, roof and floor elements for domestic and commercial applications.

3.7.11 Trussed rafters / Trusses

Modern trussed rafters are individually designed prefabricated structural components made from strength-graded timber members of the same thickness, joined together with punched metal plate connectors. Metal plate connectors would be considered semi-rigid; however, there are different forms of systems that can be formed from stiff glued joints to pinned bolted connections depending on the structural use and available fabrication methods.

Trusses provide a structural framework to support the roof fabric of building, room ceilings and, in some cases, floors. They are generally spaced at 600mm centres or less, replacing the 'common rafter' in a traditional or 'cut' roof, hence the term 'trussed rafter.'

In addition to roof systems, trusses can be formed to act as support to floors, scaffolding systems, bridges and overhead gantries. Truss systems can also be used to provide bracing and stability in both the horizontal and vertical plane in shear wall systems for example.

3.7.12 Timber cladding

Timber cladding is a non-structural application which acts as an exterior coating on a structure providing both weather protection and architectural character. Timber cladding has been used extensively across the world and is now becoming more prevalent in the UK due the environmental benefits obtained from the use of timber. A large number of species can be used as well as modified timber species. Cladding boards are often profiled and fastened to the building exterior by nails or screws.

Activity

List some of the engineered wood products which your company uses

Glue-Laminated Timber (Glulam)

Cross-Laminated Timber (CLT)

Laminated Veneer Lumber (LVL)

3.8 Wood-based panels / Sheathing materials

Wood-Based Panels are manufactured composite products comprising predominantly timber in the form of timber strips, chips, strands, particles, veneers and/or fibres - which may in some cases be the by-product of timber processing - which are adhesively bonded together using a variety of methods.

The most common categories of Wood-Based Panels for timber frame construction are described in the following sub-sections.

3.8.1 Plywood

Plywood is a flat panel made by bonding together, under pressure, a number of thin layers of veneer, often referred to as plies (or laminates). Plywood comprises an assembly of layers glued together with the direction of the grain in adjacent layers usually at right angles. Plywood is a versatile product with a high strength-to-weight ratio and can be used for a variety of applications.

As well as preservative treatment OSB can be treated with flame retardant (FR) and water repellent (WR) chemicals for increased fire performance and resistance to moisture.

Typical applications: floor decking, wall sheathing, flat roofing, concrete formwork and external cladding.

3.8.2 Oriented Strand Board (OSB)

OSB is a highly versatile engineered wood-based product typically manufactured from long stands of wood, bonded together with a synthetic resin adhesive. OSB typically comprises of three layers, the strands in the external layers being oriented in the particular direction (usually in the long direction of the board) whereas the internal layer is generally oriented at right angles to the external strands. OSB boards are typically available either with square edges or edges with a tongue and groove profiled and are available for both structural and non-load bearing applications.

- OSB is available in 4 grades:
- OSB/1 for general purpose, non-structural applications in dry conditions
- OSB/2 for structural applications in dry conditions
- OSB/3 for structural applications in humid conditions. OSB/3 is the most commonly used grade of OSB for timber frame construction
- OSB/4 for heavy duty structural applications in either dry or humid conditions.

As well as preservative treatment, OSB can be treated with flame retardant (FR) and water repellent (WR) chemicals for increased fire performance and resistance to moisture.

Typical applications: floor decking, wall sheathing, roof sarking, I-joist web material, furniture and packaging.

3.8.3 Particleboard / Chipboard

Particleboard is manufactured from particles of wood (wood flakes, shavings, chips and sawdust) and/or other lignocellulosic material (flax fibre, hemp, straw) using a combination of pressure and heat.

Wood chips are refined to wood fibre by the aid of steam and then dried. Adhesive is added to form a mat of wood particles and pressed until the adhesive is cured. After cooling the boards are cut to the required size.

According to BS EN 312:2010 there are 7 types of particleboard:

- P1 general purpose boards for use in dry conditions
- P2 boards for interior fitments (including furniture)
- P3 non-load bearing boards for use in dry conditions
- P4 load bearing boards for use in dry conditions
- P5 load bearing boards for use in humid conditions
- P6 heavy duty load bearing boards for use in dry conditions
- P7 heavy duty load bearing boards for use in humid conditions

Typical applications: domestic, office and mezzanine flooring, kitchen units and worktops, shop fitting and furniture.

3.8.4 Other varieties of particleboard

Flax-board is a type of particleboard, manufactured under pressure and heat from flax shives, with the addition of an adhesive which contains at least 70% flax and which can also contain other raw materials such as wood particles. Due to its special properties, flax-board offers several advantages over normal particleboard such as lightweight, improved fire resistance and acoustic properties.

Typical applications: fire resistant door cores and partitions, used for filling purposes and veneering, acoustic doors and partitioning, profile pack bearers, table tennis tables, warehouse shelves and worktops.

Cement-bonded particleboard (CBPB) is engineered from a cement wood mix to produce a fire resistant panel. Manufactured under pressure, based on wood or other vegetable particles bound with hydraulic cement.

Compositions vary and as such CBPB may contain other additives. Due to its composition, mass and lay-up CBPB has high durability stiffness, good reaction to fire and sound insulation.

Typical applications: internal wall construction in public places, construction of public ducts, lining of a lift shafts, soffits, cladding of prefabricated house units and motorway acoustic fencing.

3.8.5 Fibreboards / Wood fibreboard

Fibreboard is a wood based panel with a nominal thickness of 1.5mm or greater, manufactured from lignocellulosic fibres with application of heat and/or pressure. Fibreboards can be classified as either wet process boards or dry process boards.

Wet process boards are fibreboards which have a moisture content of more than 20% at the stage of forming. Boards are made by reducing steamed wood into fibres and mixing it with water to form slurry which is later formed into a mat ready for heated pressing, which promotes the bond of the fibres using the natural adhesive present in wood.

The final product could be either hardboard, medium-board or soft-board; depending upon the degree of pressing involved.

Typical applications:

Hard-boards – I-joist webs, drawer bottoms and unit backs, caravan interiors and door facings

Medium boards – pin-boards and components of partitioning systems, ceiling and wall lining panels

Soft-boards – pin-boards, acoustic absorbent and underlay materials, impregnated soft-boards can be used as a sheathing material in timber frame construction.

Dry process boards (MDF) are fibreboards which have a fibre moisture content of less than 20% at the stage of forming. In this case the adhesive is added to already dried fibres, which are then pressed in a similar way to particleboard. The end product is often referred to as medium density fibreboard. MDF has smooth and relatively dense surfaces, ideal for painting and laminating, it is also easy to work with, can be cut, profiled around the edges without splintering and breakouts.

Typical applications: skirting panels, window-boards, decorative façades, wall linings, core material of floorings, furniture production, interior fitments, shop fitting and display.

3.8.6 Magnesium Oxide (MgO)

Although not considered a wood-based material MgO is used in many similar applications as an equivalent product. MgO is typically manufactured using a mix of Magnesium Oxide, Magnesium Chloride and water reinforced with fibrous mesh layers, cured to form rigid boards.

Typically, MgO boards are used as a substitute for traditional sheathing materials such as OSB or plasterboard for applications where there is a requirement for increased fire resistance.

MgO boards are dimensionally stable when exposed to moisture and are resistant to mould and insect attack, contain no radioactive substances, asbestos nor formaldehyde and can be worked without the requirement for special tools.

The composition of MgO boards may vary from manufacturer to manufacturer and may also include additional materials such as timber fibres, silicate and perlite for example. Bearing this in mind note that the performance characteristics of MgO panels as produced by different manufacturers may vary.

Typical applications: wall sheathing, ceiling lining, fascias, soffits, tile backing.

For further information please refer to the Magnesium Oxide Based Board Trade Association (MOBBTA).

Important: when using MgO boards ensure that the fasteners are matched to the specification of the board.

Further reading: STA Product Fire Mitigation Paper 3

http://www.structuraltimber.co.uk/library

Activity

List some of the wood-based panels which your company uses

3.9 Certification

Certification schemes for sustainable forest management ensures that timber is legally and responsibly sourced from well managed and sustainable forests which are managed in such a manner that biodiversity and natural ecological processes are maintained and that they are both socially and economically beneficial.

There are currently four certification schemes recognised by the UK Government.

These four schemes are considered equivalent by UK Government policy where purchasing timber and timber products is concerned:

- Programme for the Endorsement of Forest Certification (PEFC)
- Forest Stewardship Council (FSC)
- Canadian Standards Association (CSA)
- North American Sustainable Forest Initiative (SFI)

3.10 Timber grading

All timber which is used structurally must be strength graded by an approved body, either by visual means (visual grading) or by using a grading machine (machine grading) in accordance with the relevant standards. Combinations of timber species and grade are grouped into strength classes which each have characteristic material properties which can be applied to all the species and grade combinations within the specific class.

3.10.1 Strength grading

Strength grading of timber is not about the strength grade – it is about the properties of the timber. A strength grade or, more strictly, strength class i.e. C16 and C24, is just a convenient set of properties that allow ease of trade. That is not to say it isn't important – it's just not the most important thing.

Strength grading is a non-destructive assessment that identifies and rejects the poorer pieces of timber to improve and guarantee the properties of what is passed. It uses information about the piece of timber to predict strength, stiffness and density without causing damage to the timber.

Timber is a natural material and as such its properties may vary, even within a single species. This has an effect not only on appearance but also the strength and stiffness of timber. In order to predict how timber will perform in service, strength grading has been developed in the form of non-destructive tests which makes a prediction of the structural properties of a piece of timber.

Irrespective of the construction material, an engineer needs values of strength, stiffness and density, to use in design calculations, that allow for the fact that there is never perfect knowledge of the properties of any individual piece.

For the structural Eurocodes, the value for timber strength and density is taken as the value below which no more than 5% of the pieces in the grade are likely to fall. For stiffness, it is the mean value. These are known as characteristic values.

The process of grading ensures that the timber that is passed has, collectively, at least the properties specified for the grade. There will still be variation in the properties of the pieces of timber that have passed, but this has been quantified by the grading. Even though grading decisions are made piece by piece, the properties of a grade are statistical descriptions of the graded population. They are not, and cannot be, actual or minimum possible properties of any individual piece. This is why it is incorrect to regrade timber without taking special steps to account for the original grading.

For historical and practical reasons, strength grading is done according to two approaches: visual strength grading and machine strength grading. The underlying principle is, however, the same for both.

Visual strength grading works by assessing features such as the size and position of knots, the ring width, and the slope of grain.

For machine strength grading, the range of predictive techniques has expanded from the original mechanical stiffness measurements (bending graders) to incorporate a range of sensing technologies including moisture content, density, x-ray scanning, acoustic velocity, slope of grain and digital image recognition. In both cases, the grading process is underpinned by destructive testing data.

A strength class is a standard set of strength, stiffness and density properties that provide a convenient means of specifying structural timber. So, when timber is graded, it is usually assigned to a strength class which it is at least as good as.

The strength class is denoted by a letter followed by a number indicating the characteristic bending strength of the strength class, given in N/mm^2. Softwoods are typically allocated C (coniferous) and hardwoods D (deciduous) grades.

The strength classes C16 and C24, commonly used in the UK, are two of the strength classes defined in BS EN 338 Structural timber. Strength classes. This standard contains many other classes including ones for temperate and tropical hardwoods, and for tension elements. Not all strength classes are in BS EN 338, for example TR26, which is commonly used for trussed rafters.

3.10.2 Grade stamp

The UK has a long history of marking graded timber with a stamp – so that there is no risk of graded timber being misidentified and enabling the installed timber to be inspected to check the correct grade has been used. This is customarily known as a "grade stamp" but in the language of the European Standards it is a "marking".

Clause 7 of EN14081-1:2016 allows marking by two methods:

- Method A – Individual piece marking: each piece of graded structural timber shall be clearly and indelibly marked
- Method B – package marking: each package of graded structural timber shall be clearly and indelibly marked with a label attached to the package.

Machine graded timber has to be piece marked (method A) but visual graded timber may be piece marked, or packaged marked (either method A or B).

The grade stamp must include the following information:

- manufacturer name and/or logo
- declaration of Performance (DoP) reference/number (an identification code)
- CE symbol
- strength class (or equivalent information about its performance)
- "DG" (or alternative marking meaning the same) when the timber has been dry-graded
- "M" when the timber has been machine graded.

Some examples of grading machines:

- MICROTEC GoldenEye-702
- Dynalyse Dynagrade
- Dynalyse Precigrader

Additional information may be provided on the grade stamp, so long as they do not conflict with the other items that are required to be present, or contravene the Construction Products Regulations. Some examples of such additional information:

- the number and/or logo of the notified body
- wood species or species combination
- the visual grade of the timber and the grading rule/standard
- the year in which the marking was affixed.

The grade stamp must be stamped clearly at least once on a face or edge. This rule may be relaxed for aesthetic reasons.

Some countries require preservative treated timber to be marked with the symbol "PT" (regardless of it being marked by method A or B) so that this is traceable for reuse and recycling. This is not a requirement in the UK - it is not considered practical as timber is commonly treated after being stacked.

3.11 Factors affecting strength

The range of strengths between different timber varies as widely as their densities.

The strength of a piece of timber is affected by characteristics such as:

- density: mass per unit volume
- natural defects: such as knots, wane and resin pockets
- direction and slope of grain: diagonal or sloping grain reduces strength, particularly bending and stiffness
- moisture content: generally, timber is more flexible when wet but increases in strength when it dries. Distortion can occur due to stresses as the timber dries and ruptures causing fissures or shakes
- biological degrade: caused by fungal or insect attack.

All of these characteristics described above are taken into consideration during grading.

3.12 Sawing patterns

There are many cutting patterns employed by sawmills. It takes skill and experience to get the most of every log and choose the best alignment for optimum return.

Although cutting patterns will vary between sawmills for a variety of log sizes two techniques are commonly employed:

- **Through conversion:** logs sawn through and through produce mostly tangentially sawn timber, which is the most economical production method as it does not require repetitive turning of the logs, but it produces wide boards which tend to cup on drying. Moreover, presence of the heartwood in the cross section makes it more difficult to treat and reduce the working life of the material.
- **Quarter sawing:** produces narrower boards that are more stable in drying and in use. Conversion by quarter sawing may be used for some hardwoods but the method is expensive and produces more wastage since the yield is lower than by through and through sawing and costs are increased by the need for repeated turning of the log. The end product is, however, aesthetically pleasing and less prone to distortion.

The figure of some hardwoods,

such as oak and ash, is enhanced by quarter sawing.

Sawn timber sections have fairly rough and slightly irregular surfaces that may be further machined by fine sawing or planing to improve the smoothness or dimensional accuracy. Planed timber is used when it going to be on display, sawn timber (rough sides) is commonly used under flooring or out of sight in the attic. Planing timber on all sides is not always convenient, that's why some sawmills offer planing timber only on the required sides.

3.13 Timber treatment

Chemicals may be applied to timber for a variety of reasons and applied using a variety of methods - most commonly by pressure impregnation though hot and cold soaking, dipping, spraying and brushing are other examples.

3.13.1 Preservative treatment

There are many chemicals, used singly or in combination, which preserve timber against insect and/or fungal attack. Preservative treatment does not affect the weathering of timber and for most some form of surface finish such as paint or stain is needed to maintain the appearance, especially when timber is used outdoors.

Whether or not timber should be treated depends upon service situation, exposure to wetting conditions and biological hazards.

The most common are formulations of copper, chromium and arsenic (CCA) although new formulations are continually being developed and introduced. Although toxic to insects and fungi, CCA treated timber is non-toxic to humans and animals under normal conditions of use. Timber treated with water-borne preservatives must be re-dried to appropriate moisture content after treatment. Once dried, finishes can be applied and the chemicals are odourless.

3.13.2 Flame retardant (FR) treatment

In many cases, timber may be used in its natural, untreated state. However, in some situation enhanced 'reaction to fire' might be required. This can be achieved by appropriate flame-retardant (FR) treatments. Reaction to fire assessment is about ignitability and combustibility of material and not its ability to resist the fire. Flame retardant treatments can be applied into the product during manufacture, post manufacture or on site.

The three most common types of flame-retardant treatments are:

- impregnation with inorganic salt solutions or leach-resistant chemicals
- surface coatings
- chemicals inherently incorporated into the product at point of manufacture.

Typically, FR treatments contain dyes such that treated material can be readily identified.

3.13.3 Water repellent (WR) treatment

Water repellents are used to reduce uptake of moisture and provide improved dimensional stability and resistance to distortion.

Water repellent treatment is used to further improve the weathering characteristic of treated timber. This type of treatment is often used along other types of treatment in places where timber is exposed to external environment and in presence of the water. Water repellent causes surface water beading, improve resistance to distortion and dimensional stability.

Typically, WR treatments contain dyes such that treated material can be readily identified.

Activity

Explain the purpose of preservative treating timber

3.14 Timber types and species

Botanists generally divide timber into two main categories, softwoods and hardwoods.

These terms can cause confusion, but simply softwoods come from coniferous, or needle leaved, trees whereas hardwoods are from deciduous trees and evergreen broadleaved trees.

The terms softwood and hardwood are botanical rather than indicating end use.

Some key characteristics and differences between softwoods and hardwoods:

Softwoods

- Fast rate of growth, most of the trees can be felled after 30 years
- Low density timber resulting in relatively low strength
- Has to be treated to improve durability qualities
- Comparatively cheaper than hardwoods

Hardwoods

- Slow rate of growth, in some cases over 100 years
- High density timber resulting in a high strength
- Naturally durable, less dependence on preservatives
- Tend to be expensive due to the time taken by the tree to mature.

Timber strength grading is done according to two approaches: visual strength grading and machine strength grading. The underlying principle is, however, the same for both.

4. Timber frame - the basics

4.1 What is Timber Frame?

The most common use of timber frame in the UK is as a structural framing system that is then externally clad with an impermeable veneer such as brick or block but timber and other materials can also provide the rain screen.

Timber frame construction is a method of construction whereby timber members and sheathing are combined to form a structural frame which effectively transmits horizontal and vertical loads (e.g. those applied by self-weight and wind) to the foundations. A non-load-bearing outer leaf (cladding) encloses the timber frame to provide protection from the elements and aesthetics.

Typically, the inner and outer leaves of the wall have a ventilated cavity between them. Both leaves are connected together using wall ties at regular horizontal and vertical centres.

In the UK the majority of timber frame manufacturers typically produce/pre-fabricate building elements e.g. open and closed wall panels, trussed rafters, floor cassettes and roof panels, in the factory for assembly on site.

Factory manufactured timber frame guarantees the highest level of accuracy and quality and significantly simplifies construction on site.

During construction the timber frame is typically covered:

- internally with plasterboard and filled with high performance insulation
- by moisture and vapour barriers, incorporated within the building
- externally with the outer leaf of the wall which can be of any standard finish such as stone, brick, rendered block or timber.

Roofs are also constructed in timber and are supported upon the structural timber frame at internal load bearing timber wall panels and party walls.

Throughout the country you can now see the flexibility of design and layout of timber frame construction in the variety of buildings constructed in this manner.

In particular, timber frame is now proving itself in medium-rise construction up to five, six and even nine storeys.

A qualified structural engineer certifies every timber frame project. In larger projects there may also be a separate timber frame engineer.

4.1.1 Housing

Housing is timber frame's traditional market. Timber frame is used to construct everything from bungalows to multi-storey flats; from high volume quality developer housing to individually commissioned dream homes. Locations range from inner cities to offshore islands, from suburban estates to single plots.

In terms of sustainability, timber is the only renewable resource in the construction sector and contains less embodied energy than comparable building materials.

4.1.2 Industrial and commercial field

Timber frame technology is now being applied to a wide range of projects of medium-rise buildings such as:

- schools
- healthcare facilities
- community centres
- sports halls
- funeral parlours
- hotels
- business units
- churches.

4.2 Nature and extent of the Industry

Small, manually erected open panel is the most common system used in the UK accounting for approximately 80% of the timber frame market. More advanced large and/or closed panel crane erect systems are now becoming more common.

Floors can be factory produced as floor cassettes or whole units/modules/pods can be manufactured in the factory.

Timber frame is renowned for its excellence in thermal performance, acoustic performance and durability.

In terms of sustainability, timber is the only renewable resource in the construction sector and contains less embodied energy than comparable building materials.

4.3 Understanding on and off site construction

Timber frame construction is one of the quickest methods of construction. The foundations can be laid and the structure erected and made wind and watertight in approximately 4-5 days. This duration can, if necessary, be reduced even further via a number of means.

Offsite construction, where elements are assembled in the factory then delivered to site as and when required i.e. on a 'just-in-time' basis, is an effective means of reducing the duration and increasing the efficiency of timber frame construction.

4.3.1 On site construction

In the context of traditional masonry construction typically both the internal and external leaves consist of brick and/or block and are for the most part constructed on site with the inclusion of some sub-assemblies. Typically, the process of traditional construction takes longer than that of timber frame construction as generally, but with some exceptions, mortar curing times have to be allowed for before floors can be used as safe working platforms and before roofs can be loaded for example. Traditional construction doesn't lend itself as well to the integration of timber elements constructed off site e.g. floor cassettes.

In the context of timber frame construction the operations that are undertaken on site comprise ground-works, setting out, erection of the timber kit, installation of services, internal finishing and completion of the external envelope.

Timber frame buildings may be constructed 'from scratch' using loose materials which are processed, assembled and erected on site with little or no prefabrication of the main elements of the timber frame in the factory, though this has become much less common and is typically limited to post and beam construction.

Typically, however at the very least timber frame (open) wall panels and trussed rafters are fabricated in the factory and delivered to site for erection.

Construction on site is subject to weather conditions. It is important that construction on site is well coordinated and undertaken in a quick and efficient manner to ensure that buildings are made wind and water tight quickly.

It may be more challenging to supervise and control labour, skills and quality on site than in a factory environment.

Construction on site generally takes longer as there is less scope to run operations concurrently when compared to offsite construction.

4.3.2 Offsite construction

Offsite manufacture involves the pre-assembly of construction components, elements and/or modules in a factory before installation into their final location on site. Offsite manufacture involves a range of construction methods described in detail later in the 'Knowledge' section.

Prefabrication can cover off-site prefabrication of materials and parts, prefabrication of components and sub-assemblies, as well as volumetric units or modules.

Operations are undertaken in the factory in controlled conditions, utilising a skilled workforce, unaffected by external climate and environmental conditions.

The main benefits of offsite construction are:

- **Improved quality and consistency:** work is undertaken in a controlled factory environment, ensuring consistency and improved quality
- **Technical improvements:** enhanced levels of thermal and acoustic performance as a result of an improved quality assurance process and investment in research and development
- **Reduced time scales:** increased speed of construction as activities are undertaken concurrently rather than sequentially
- **Weather:** offsite construction is not weather dependent and so not exposed to risk of delays caused by adverse weather conditions
- **Waste:** control and optimisation of materials, use of CAD/CAM software, automation and standardisation of processes ensure that the production of waste is minimised
- **Storage:** reduction of on site storage requirements
- **Flexibility:** standardised component parts coupled with a mass customised approach ensures variation
- **Increased safety:** more operations are undertaken in a controlled factory environment
- **Environmental impact:** efficient use of materials responsibly sourced via a qualified supply chain, which are then used optimally to produce components to be assembled on site to provide a structure with enhanced building fabric performance
- **Economic impact:** utilising a local labour force to efficiently add value to a localised supply chain for the delivery of a product of higher quality
- **Social impact:** the factory

Activity

Can you think of any of the other benefits of offsite construction?

environment improves working conditions and offers a change in construction culture by providing a safe, clean place of work with improved job security and flexible shift patterns

- **Customer satisfaction:** reduced number of defects resulting in less snagging works.

4.4 Modern methods of construction

Modern methods of construction (MMC) is a collective term encompassing a number of modern construction methods which differ from those used traditionally. MMC includes a wide range of processes and technologies which involve pre-fabrication and off-site manufacture.

Timber frame is a modern method of construction and though not a building system there are a variety of systems and combinations of systems on the market which are based upon the principles of timber frame construction.

4.4.1 Platform frame/ Panelised/Small panel construction

Currently the most common method of timber frame construction. Components are assembled off-site in timber frame factories. The softwood timber studs are made into panels (typically between 2400-2700mm long and 2400mm high).

They are then sheathed on one side with a timber panel product like plywood or more commonly oriented strand board (OSB).

This is then finished externally with a breather membrane, taped then delivered to site where the panels are hand manoeuvred into position and nailed together using nail guns.

Using this method each storey is installed as a separate operation and each preceding floor used as a safe working platform for construction of the next.

Typically, insulation is added to the stud bays on site before finishing with an internal lining, typically plasterboard. Joints, junctions and fixings are taped and filled.

This method may utilise pre-insulated panels i.e. sheathed on both sides (internally and externally) with insulation installed in the factory prior to delivery on site.

4.4.2 Platform frame/ Panelised/Medium and large panel construction

These are similar to small panel, only the medium panels can be 3600-4200mm long. Medium panels require a crane to be erected as they are too heavy to handle and manoeuvre by hand.

Similarly, large panels with lengths between 4200mm and 12000mm can be erected on site using a crane. This allows for room layout flexibility when designing timber frame buildings.

The most common form of construction (large or small panel) is generally referred to as platform frame as the wall panels form a platform on which the next storey wall panels sit. Crane erection also enables the use of whole-room construction or volumetric techniques discussed elsewhere.

4.4.3 Floor to floor panel frame

Wall panels are storey height rather than floor to ceiling height. Intermediate floors are supported upon and between wall panels resulting in reduced cross sectional vertical shrinkage. This is a very commonly used construction method.

4.4.4 Post and beam/Stick built/Balloon frame

Components cut offsite and assembled onsite using simple hand tools. This is most common in Japan, the US and Canada and can also be seen in Scandinavian countries in the summer months. Generally, in the UK its use is restricted to specialist companies.

4.4.5 Volumetric/modular

Three dimensional units entirely produced in a factory to form compartments, individual rooms or sections of the structure. Windows, doors, linings, services, cladding etc. may be installed in the factory. Rooms which generally rely on having a higher concentration of services such as toilets, bathrooms or kitchens can be assembled as complete 'pods'. Pods tend to be non-structural elements and incorporated during construction into a load bearing structure. As well as the applications noted above pods may also be used to accommodate services such as heating equipment.

This can include complete buildings where the completed usable space forms part of the completed building or structure finished internally (lined) and externally (clad).

Volumetric construction offers reduced time onsite and increased quality as a result of rooms being fully assembled with the follow-on trades, in a controlled factory environment.

Volumetric construction proves most efficient where large quantities of identical units are to be produced. Panellised forms of construction are likely to prove more cost effective and efficient where there are a large variety of unique layouts.

Prior consideration must be given to logistics (factory handling, storage, transportation and site erection)

Foundations and soleplates must be accurate and within tolerance to accept the units on site.

4.4.6 Hybrid

Hybrid, or semi-volumetric, construction employs a combination of the above systems or approaches i.e. volumetric and panelised hybrid. This encompasses a wide variety of forms, systems and applications. Most commonly volumetric units are integrated with panellised systems. Hybrid structures may also refer to structures where timber is used in conjunction with another structural material, most commonly steel or concrete.

Commonly timber is used with steel to create long span structures where steel is used in areas of high stress and timber (often glulam or LVL) is used elsewhere.

Timber to concrete hybrid systems can be in the form of timber elements resting on concrete supporting structure. Timber to concrete hybrid systems can also be used for individual elements such as timber to concrete composites or timber aggregate concrete.

The theory behind this type of structure is to utilise the key mechanical properties of all materials and build methods.

The aim of hybrid structures is to optimise a design by utilising the most suitable material and build method for a given application. A sound understanding of materials and methods must therefore be applied to identify suitable arrangements.

There will be a variance between the strength, stiffness and degradation of construction materials when used in conjunction with one-another. The effect of these on a structure must be evaluated. The interface between materials is the critical area of the design and may be the most complex to analyse.

Activity

What method(s) of construction does your company use?

4.4.7 Sub-assemblies

Simple assembled components incorporated into structures, although not complete systems. These are most commonly assembled in the factory but may also be assembled on site e.g. staircases, doors and windows.

4.5 Manufacturing systems

There are a variety of methods of timber frame manufacturing. The most common manufacturing systems are described below.

4.5.1 Open panel

Single sheathed panels comprising a structural frame, typically studs at regular centres affixed to top and bottom rails, typically of the same material and section size, and sheathed on one side with a structural sheathing board and a breather membrane applied as appropriate, although the breather membrane may be fitted onsite. Insulation, internal linings, windows, doors, services, other membranes etc. are typically fitted on site once the open panels have been installed.

Panels may be either load bearing (structural) or non-load bearing (separating walls and partitions).

The panels are made 'open' on one side to receive insulation and services on site and are 'closed' by the internal lining material.

This system has a proven track record in the UK market and accounts for approximately 80% of timber frame used in the UK.

Open panels are easily fixed to the sole plate using nails or screws directly through the bottom rail before internal linings are installed.

4.5.2 Pre-insulated (closed, enhanced) panel

Pre-insulated panel construction involves the creation of a structural element ready for installation offsite before being delivered to site. Pre-insulated panels consist of a structural frame (top and bottom rails connected by studs, usually at 400-600 mm centres). The structural frame may consist of solid timber, engineered timber systems or similar. The panel is then fitted with sheathing, membranes and insulation as per design.

For pre-insulated panels the insulation material is installed into the panel in the factory and this is then retained with some other layer of material to close the panel. As well as installing insulating material prior to closing the panel it may also be blown in once sheathing has been installed on both faces of the panel.

The frame structure is created with studs at prescribed spacings. Openings and reinforcing elements are inserted as per the design requirements.

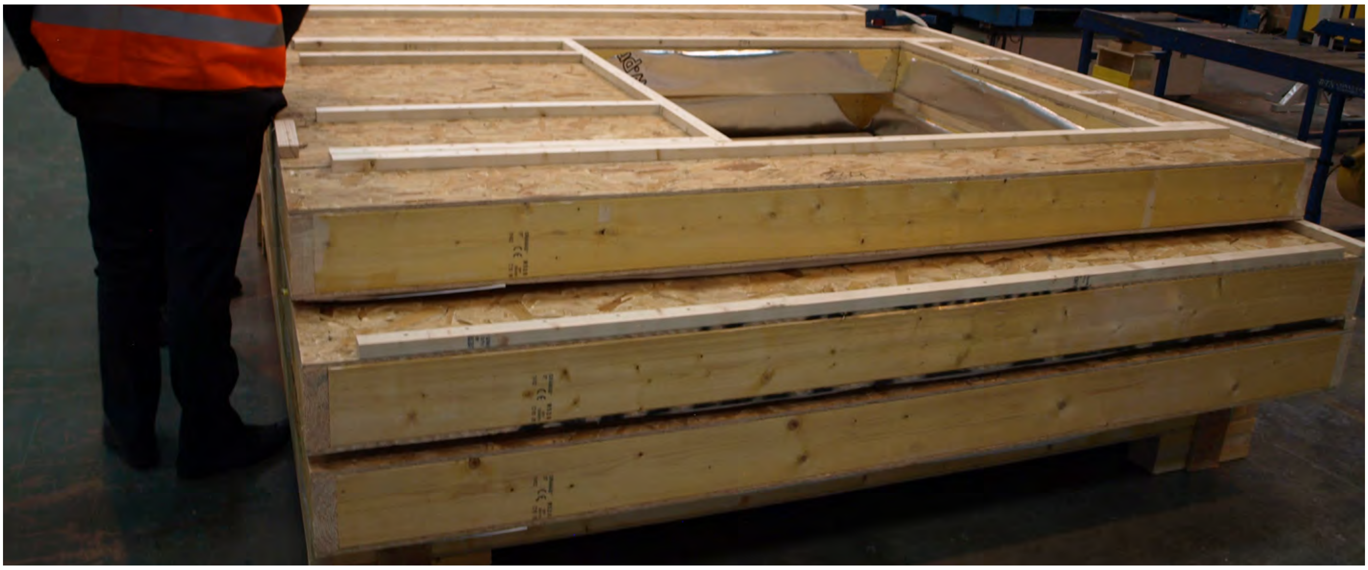
Sheathing boards are then secured in place using mechanical fasteners at prescribed spacing.

Pre-insulated panels may have services, windows, doors, finishes and cladding installed in the factory.

Closed panel systems generally allow more value to be added in the factory but often require service runs to be pre-planned. As they are also heavier than open panels, pre-insulated panels tend to require handling in the factory and erection on site by mechanical means.

Pre-insulated panels are used to create wall structures within timber structures. The timber frame

Open Timber Panels consisting of a timber stud frame and OSB on one side.



Closed Timber Panels consisting of a timber stud frame, insulation, OSB on both sides and battens for the services.

transfers loads applied from any structural elements above to either a floor system or the structure's foundations. The sheathing provides lateral or racking strength to the wall system.

Closed panel systems are used predominantly in domestic dwellings, however they can be used in low to medium rise buildings.

Panels should be loaded appropriately using lifting equipment and stacked either vertically or horizontally. They should also be wrapped with plastic to prevent water ingress during transport.

Installation should be carried out as soon as panels are delivered, storage on site should be undertaken in accordance with manufacturers guidance. Panels are typically connected via a soleplate to a load bearing sub structure.

Innovative fixing details to sole plates are required as there is no access to top of the bottom rail due to sheathing being affixed to both faces of the panel.

4.5.3 Floor and roof cassettes

Floor and roof cassettes are similar in configuration to closed panel timber frame elements. Cassettes generally comprise a frame structure, insulation, connectors and sheathing.

Common practice within the timber frame industry is to include engineered timber products such as I-joists or open web joists into the structure.

The cassette is manufactured offsite and installed onsite, reducing site costs and time as well as increasing product quality.

A significant advantage of floor cassettes is that once landed and secured they provide a safe working platform, enhancing speed and health and safety on site.

Internal elements are placed according to design specification on framing table, connected and braced using mechanical fasteners. Sheathing is then placed onto surface to create a cassette.

Cassettes should be loaded onto a flat-bed for transportation. Care must be taken to lift cassettes appropriately to ensure panels are not damaged due to poor lifting arrangement or reversal of forces.

Cassettes should be stacked horizontally and wrapped before transportation to prevent water ingress.

Cassettes are typically lifted into place using appropriate lifting apparatus and connected to the supporting structure.

Installation and site storage should be undertaken in accordance with the manufacturer’s specification.

Floor and wall cassettes can be used in a variety of applications from domestic dwellings to large scale industrial units.

By utilising engineered timber products into cassettes structural performance can be enhanced with the potential for large spans.

4.6 Building design

Timber frame systems are designed to operate to tight tolerances so lend themselves well and are compatible with the use of IT.

Timber frame manufacturers produce their own drawings before commencing manufacture.

Most manufacturers in the UK will operate Computer Aided Design (CAD) software to take bespoke schemes and produce timber frame solutions.

4.6.1 Computer aided design (CAD)

A computer aided design tool acts as a platform for the end user to produce a customised conceptual design based on the standard components that reflects their requirements.

These produce panel layouts, material take-off and cutting lists. In some instances the software also controls the saws in the factory to optimise the useful material from each piece of timber and minimise waste.

It is important for designers and clients alike to understand that timber frame can provide flexible design solutions, rather than rigid boxes often portrayed. Conversely, it is also necessary to expect that to reduce waste (materials, labour, design time, etc.) it will be necessary to work with standard

Activity

What manufacturing system(s) does your company use?

components wherever possible to maximise the manufacturing efficiencies.

The structural design of all timber frame buildings must be approved by a structural engineer.

4.7 Building manufacture

The use of CNC and CAD/CAM technologies for manufacture offer a number of benefits.

4.7.1 Computer numerical control (CNC)

A CNC machine is a production machine that is controlled electronically via computer technologies to reduce production time and increase quality and efficiency. The CNC machine therefore uses digital information to control the movements of tools and parts for processes such as cutting.

4.7.2 Computer aided manufacture (CAM)

Controlling the manufacturing machines utilising computer software is regarded as computer aided manufacture, if this is

Activity

List some CAD packages which you are familiar with and/or which your company uses, or which you use to exchange information with customers andexternal companies integrated with the CAD it is regarded as CAD/CAM.

Most manufacturers use production lines to assemble components, panels and units.

Standard panels are produced on the production line and the more complex elements are often completed as sub-assemblies.

Completed panels are then loaded in reverse order onto trailers so that the first panels unloaded are the first panels required on site.

All design work has to be completed prior to manufacture.

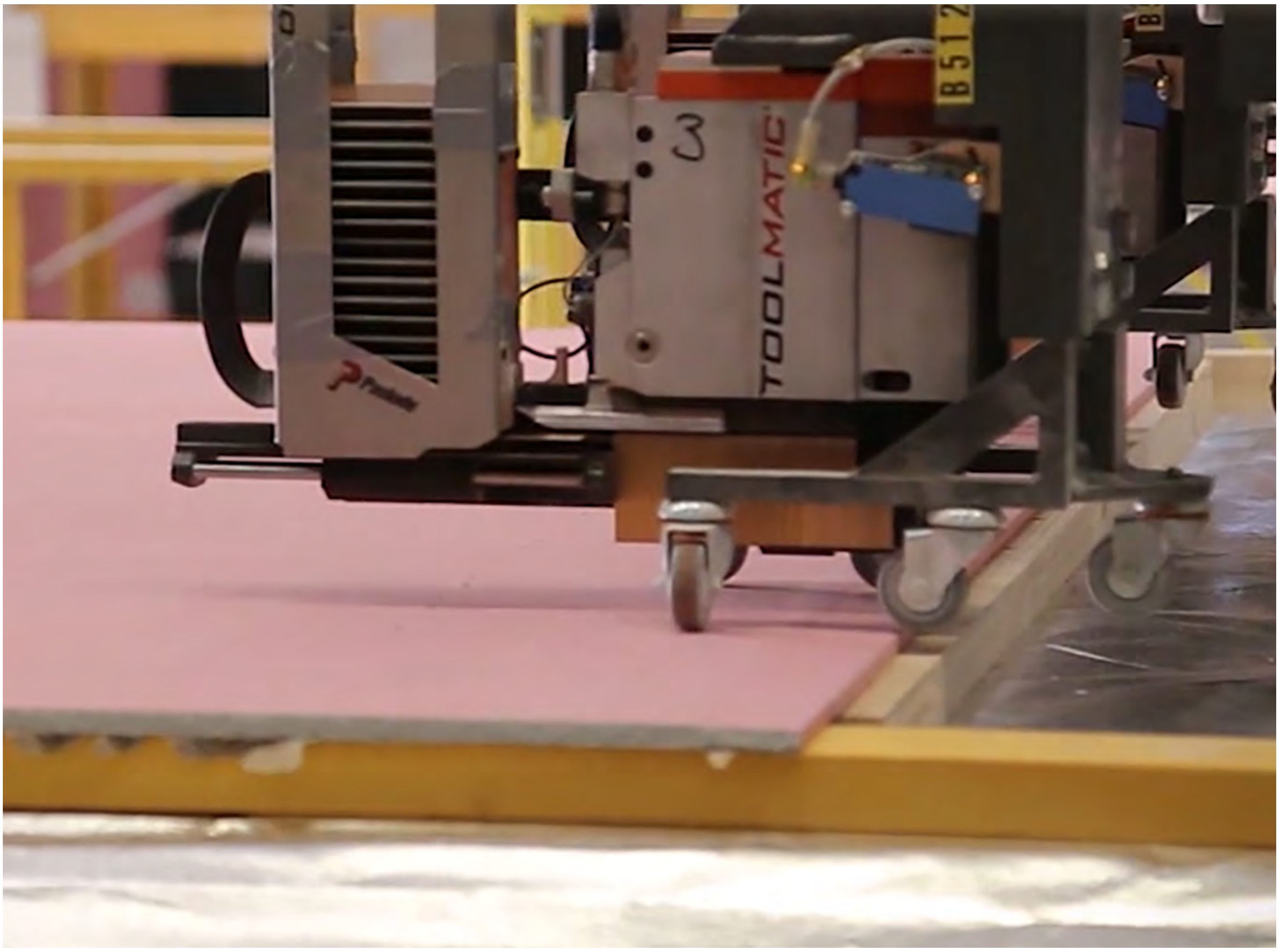
Some of the main benefits of utilising CAD/CAM are as follows:

- standardisation of products and materials
- optimised use of materials
- increased accuracy
- ability to process more complex jobs
- improved efficiency and speed
- improved job planning and control
- reduction in human error
- data access, handling, revision and sharing.

Activity

You should now have a general understanding of timber frame construction. Write a short description of your understanding of what a timber frame structure is, including some of the components that might be incorporated.

Computer-Aided Manufacturing (CAM) equipment cat work with different materials: timber & plasterboard.



5. Benefits of timber frame

Activity

List some of the main benefits of timber frame construction. Consider the benefits to the builder, developer and end user

5.1 Overview

Timber frame has many benefits to the builder, developer and end user (when compared with other methods of construction i.e. traditional masonry) but in order that those are achieved they must be designed, detailed, manufactured, assembled and erected with care and attention.

5.2 Main benefits

The main benefits of timber frame construction to both the builder, developer and end user which you should have included are outlined below.

- **Offsite construction:** allows for pre-assembly in a controlled factory environment to enhance quality, accuracy, workmanship and safety

Lean principles, adapted from the automotive industry, are applied in off-site timber manufacturing to increase efficiency.

- **Speed of construction and productivity:** reduced individual build and build programme times in comparison to traditional masonry construction
- **Non dependence on weather:** elements can be constructed in the factory and can be erected in adverse weather conditions potentially reducing the risk of delays
- **Improved planning:** timetables are more predictable enabling schedules to be more easily adhered to, targets achieved on time potentially reducing the risk of delays
- **Simultaneous processes:** construction processes can be undertaken simultaneously and internal works can commence earlier in the build programme. Outer cladding elements are removed from the critical path
- **Reduced drying times:** no mortar curing times on the inner leaf
- **Reduced materials handling, distribution and on-site storage:** timber frame buildings typically comprise fewer single elements
- **Design flexibility and versatility:** flexible design solutions and greater scope for creating unique structures
- **Potential for reduced build costs:** savings can be made on materials, plant and labour
- **Improved site productivity:** more efficient use of plant and labour
- **Reduction of waste:** efficient use of materials, starting at the design stage
- **Engineered components:** utilisation of engineered wood products. Greater versatility
- **Installation of services:** provision of routes for services
- **Sustainability:** timber is a sustainable resource
- **Improved quality and consistency:** manufactured in controlled conditions.

5.2.1 Traditional build method

In addition to the benefits outlined above, timber frame construction is a traditional build method. Timber is the oldest construction material known to man. Modern timber frame construction has evolved over many centuries and there are still many such structures still standing which were built over 200 years ago.

5.2.2 Strength and durability

A correctly constructed timber frame building is at least as strong and durable as a building constructed using any other material. Structural engineers produce calculations to prove that the timber frame will not only support the building and cladding materials, but will also withstand the local wind conditions and other exposure factors. Timber frame structures are also very resilient and can withstand impact far better than masonry structures.

5.2.3 Energy efficiency

The performance of standard construction is higher than that demanded under current legislation. The high level of insulation means that the structures are extremely economic and offer reduced running costs. U-value calculations can be produced to enable heating engineers to design the most appropriate system.

5.2.4 Precision and versatility

Timber frame components are manufactured under strict quality control with set tolerances. This means, for example, that right angles are true, verticals are plumb and edges are straight.

The flexibility of timber frame allows design features such as jetted floors and cantilevers, that would not normally be economic, to be incorporated.

A timber frame building can be clad with any number of traditional materials, both internally and externally, which enables it to harmonise with the local surroundings.

5.2.5 Environmentally friendly

The major man-made cause of carbon dioxide (CO_2) emissions in the UK is the burning of fossil fuels for heating and power. A timber frame building containing a high level of insulation reduces the amount of energy required to heat it. In addition to this, the embodied energy costs in producing the building materials are considerably less than those in other forms of construction.

Only timber from managed forests is used in the manufacture of timber frame components. Harvesting mature trees and replanting new ones creates a natural cycle. Also, more trees are planted than are felled, so an increase in the volume of trees is created. Growing trees absorb carbon dioxide and, by photosynthesis, convert it into oxygen. Once a tree is mature it reaches the maximum of its capacity for carbon sequestration.

After around 50 years the CO_2 adsorption decreases, and hence replanting mature trees with young trees increases a forest's ability to absorb carbon dioxide.

5.2.6 Other considerations

Some other considerations you should be aware of:

Planning: all planning authorities accept timber frame homes and process applications for planning permission in the same manner as for other dwellings.

Fire safety: timber frame homes meet all the requirements for fire safety as specified in the current Building Regulations. More information regarding fire safety is available in a later section of this workbook.

Mortgages: timber frame construction is treated in exactly the same way as other construction methods.

Activity

Identify and provide a brief description of some of the works that are involved during the various stages of design, manufacture and erection.

Design stage works description

Manufacturing stage works description

Erection stage works description

5.3 Processes – fabrication design, manufacture and erection

Some of the activities and operations commonly undertaken at each stage throughout the construction process which you should have included are outlined below:

- **Timber Frame Engineering:**
  - production of drawings (layouts, sections, details)
  - calculation of loads acting on the timber frame
  - specification of timber cross sections
  - calculation of connection loads
  - specification of connector size and performance
  - compliance with relevant standards.

- **Fabrication Design (drawing office):**
  - production of drawings (assembly, architectural, site plans, services, erection etc.)
  - cutting lists, material lists/ take-offs, loading lists, fastener schedules
  - specification of connector types
  - scheduling – materials and delivery
  - preparation of contracts and administration work
  - liaison with engineers and architects for the architectural drawings and structural appraisal
  - liaison with manufacturers and suppliers
  - liaison with Client
  - liaison with factory and site.

- **Manufacture (factory)**
  - health and safety – safe operation at all times
  - adherence to drawings, specifications and standard details
  - adherence to work schedule
  - cutting and preparing materials
  - assembling panels
  - assembling cassettes
  - assembling modules
  - installation of membranes
  - installation of fire stopping measures
  - preparing components and assemblies
  - installation of services
  - installation of linings
  - installation of sub-assemblies
  - storage (materials, finished assemblies and units)
  - packing and sorting materials
  - loading materials
  - receipt and delivery of goods/finished items
  - checks and quality control
  - reporting and rectifying errors.

- **Erection(Site):**
  - health and safety – operate safely at all times
  - correct interpretation of and adherence to drawings and specification
  - adherence to site assembly drawings and instructions
  - adherence to work schedule
  - site inspection
  - provision of Services and drainage
  - setting out and laying sole plates
  - erection and management of scaffolding

The timber frame building design, manufacture and erection processes are collaborative in nature and involves a lot of team work.

- kit checks upon arrival
- Installation of ground floor, where part of the timber frame package
- erection of ground floor walls
- installation of upper floors
- erection of upper walls
- erection of roof structure
- landing and fixing modules
- external cladding
- provision of appropriately filled and/or covered settlement gaps
- installation of temporary bracing
- installation of perimeter and partition noggins
- installation of membranes, where part of the timber frame package
- installation of insulation
- metalwork correctly specified and installed
- installation of services by follow-on trades
- installation of tie down and restraint straps
- installation of membranes for moisture control and air tightness
- installation of cavity barriers
- management of plant
- considerate storage of materials
- checks and quality control
- reporting and rectifying errors and repairing damage
- handover (signatures where necessary)
- snagging.

Activity

Identify and provide a brief description of the main supply chain stages involved during design, manufacture and erection.

5.4 The supply chain

The main supply chain stages you should have included are:

- **Forestry:** timber is harvested from a certified, managed and sustainable resource
- **Milling:** processing of the timber at the sawmill
- **Treatment:** timber is treated with a preservative, water repellent and/or fire retardant treatment where applicable
- **Architecture:** buildings are designed by an architect or previous architectural designs and specifications are used
- **Engineering:** the forces on the frame are calculated, the arrangement and materials are specified by an engineer
- **Timber frame design:** the architectural design are passed to the timber frame business in-house fabrication designers manufacturer to design and specify the timber frame kit
- **Timber frame manufacture:** the manufacturers produce the elements as specified by the in-house fabrication designers
- **Marketing:** manufacturers advertise their products to potential customers
- **Private and public sector:** manufacturers target house builders and housing associations as potential customers
- **Construction companies:** these are major players and will be kept informed of the benefits of building with timber frame and the advancement of technology and methods
- **Site erection:** the final stage where everything comes together: after the foundations and sole plates, the timber kit is erected, the subsequent trades complete the roof, exterior and the interior of the building.

6. History of timber frame

This section provides you with a short history of timber frame buildings and their origins.

6.1 Early construction

The dates of developments of timber frame in the UK vary depending on the locality. The Romans, Saxons and Vikings for example all had timber frame buildings. However, timber frame construction increased in the late medieval period that started in Britain around 1200 and ended in the early 16th Century.

Across the UK, developments in house building started earlier in the wealthier south east of England and generally spread north west to the Midlands and then further north over a period of a hundred years or more.

Until around 1200 in areas with supplies of wood, many dwellings were made of posts ('earth-fast posts') pushed into the ground to keep them upright. Other wooden members, also made from young trees and branches, were added to give rigidity, and a thatched roof was added.

However, in time the posts rotted in the ground and the dwelling usually lasted no more than a generation. Indeed, the earliest timber frame houses existing today are of this construction and are believed to have been built in the middle of the 13th century. They are at Boxted in Kent, and at Upton Magna just west of Shrewsbury recently dated to 1269.

By the late 14th century timber framed peasant houses were being built in this country, many of which survive today along with similar examples in Germany, France and Canada.

The oak used for the frame was cut during the winter or spring and used immediately, partly because seasoned oak was very hard to work with. This partly accounts for the interestingly distorted timbers in old houses.

These late medieval houses, occupied by merchants, farmers, craftsmen and other prosperous people, were Open Hall Houses (a basic design that had been in use for centuries).

The largest part was taken up by the Open Hall, which was used by the master, his family, servants and farm labourers as a dining and general living area. Indeed, it was the dominant room from the wealthiest downwards until the layout was modified or replaced during the transitional period, which came at the end of the late medieval period. These changes eventually led to the modern designs of the Georgian and Victorian periods.

There was little separation into social classes as far as the mechanics of living were concerned.

The Hall was open to the thatched roof, through which escaped the smoke from a fire placed in the centre in wealthier houses, or at the side in poorer ones. There was no ceiling and no room above. The

Timber frame building was common practice not only in the UK, but across Europe as exemplified by this multi-storey building example from France.

smoke- blackened roof timbers are often a clue today that a much altered timber house was once an Open Hall House.

There are many Open Hall Houses in the UK, especially in Kent. Many have been modified over the years.

By the end of the 14th Century many substantial houses had been built in the south east of England for peasants. By the end of the 16th Century humbler dwellings were seeing the benefit of this type of construction and layout.

The ground floor was made of beaten earth mixed with clay and often animal blood as a hardener, whilst in the south east, beaten chalk and soured milk were used.

6.2 Cruck construction

A cruck consists of a matched pair of curved timbers (blades) sometimes coming from two matching tree trunks. The advantage of a matching pair included the likelihood that they would distort in the same way. They were joined at the top, and with a tie-beam halfway up, to form an "A" shaped frame.

A cruck house would have at least two of these frames to form the gable ends. They were commonly 16 feet (4.9 m) apart forming one bay. Additional cruck frames (without the tie-beam) could be provided in between as required for the length of the building.

The width of the building (the span) could sometimes be very large, especially in barns – Leigh Court Barn in Worcestershire spans over 30 feet (9 m).

The walls were then erected and these could be of stone, clay or sometimes brick that would usually conceal the timber.

Alternatively, the walls could be of timber and consist of sills, posts, rails, and infill panels as for box-frame construction, thus usually revealing the timber.

Cruck construction was common in Central and Northern England and in Wales but not in the south east, and continued to be developed and used for new building into the 19th Century.

Over 2,000 Cruck framed buildings have been identified and still stand today, although it is often difficult to detect them as such from a cursory look, often because of alterations. The best place to see them is in the Midlands, especially around Hereford.

6.3 Box frame construction

This method was more common and more widespread.

Here, a rectangular frame of sill, posts and a wall plate was erected on a stone plinth and joined by mortise and tenon joints. One frame made each of the two side walls of a bay and one side made each of the gable ends.

As in the case of cruck construction, additional bays were added to give the required length of the building.

Studding (vertical members) was installed between the posts. In the south east the studding was relatively close together, so forming tall narrow openings.

The openings were filled by infill panels to make the structure weatherproof. These panels often consisted of wattle and daub.

First, slightly oversize staves were inserted vertically about 5 to 6 inches (125 to 150 mm) apart into the rails by springing them into slots. Then lengths of split oak or hazel or ash were woven horizontally in and out of the staves to form the wattle.

Next, suitable local wet clay with straw, cow hair or cow-dung (the daub), was thrown against both sides of the wattle to form the desired thickness. It was important that the daub thrown on to one side met and adhered to the other. A thin coat of plaster was then applied and lime-washed or washed with ochre.

The oak weathered naturally to a bronze grey and although the distinctive practice of painting them black existed as early as 1822 it was made almost universally fashionable in Victorian times. Therefore the relatively recent 'magpie' look would have been almost unknown before the 1820s.

The ease of breaking the panels led to the designation 'breaking and entering' as a criminal offence, which is still in use today.

Box frame construction has continued almost to the present day, though things have moved on and today we have many different types of timber frame construction.

7. Manufacturing production line

7.1 Overview

For a number of reasons, a wide variety of production lines exist across the timber frame sector and as you might expect these vary from company to company, however regardless of the method or processes employed all achieve the same common goal in producing a timber kit of high quality which leaves the factory such that it can be erected in logical order on site. This section provides a brief outline of the manufacturing production line.

7.2 Types of process

Production plants tend to fall into one of 3 categories:

- **Manual:** processes are undertaken by hand by factory operatives. Manual lines have the maximum level of human interaction
- **Semi-automated:** mixture of manual and automated processes i.e. partially automated – some operations are undertaken manually and some automatically. Semi-automated lines require moderate human intervention the level of which depends largely upon the level of automation - the ratio of manual vs automated operations.
- **Fully automated:** variety of automated control systems for operating equipment and machinery. Savings can be made on labour and time and improvements made to precision and accuracy, ultimately resulting in a more predictable output and scheduling. Fully automated lines might be mechanical, hydraulic/pneumatic, electrical, computer driven or a combination of each. Fully automated lines may be left to run continuously without supervision and require minimal human intervention.

The designer will need to provide manufacturing information in such a format that suits the particular manufacturing process.

Activity

Is your company's production facility manual, semi-automated or fully automated?

7.3 Sequence of manufacture

The various stages and sequence of manufacture for timber frame construction can broadly divided into a number of steps, although it is important to note that the process will largely vary depending on how the company operates and the methods they employ.

A typical example of the sequence of manufacture is as follows:

- receipt of goods, inspection and storage of incoming materials and supplies
- transfer of materials to the correct location for storage or processing. (Non-conforming items to quarantine) (material batched appropriately for processing) Preparing materials and tools for the various operations to be undertaken
- selection, processing, marking and preparation of raw materials
- manufacturing of components, assemblies, units (depending on build method)
- manufacturing and construction of wall and gable panels
- application of breather membranes where applicable
- installation of insulation where applicable
- manufacturing cassettes where applicable
- finishing of all manufactured products
- inspection, quality checks and sign off
- recoding and reporting of inspection and test results
- packing (including ancillaries and additional parts as per specification) and protection for transport and storage on site
- loading for transport
- completion of all paperwork as necessary at each of the above stages.

Activity

Describe the sequence of manufacture in your company's production facility

The process flow in the factory should be optimised to ensure efficient operation and reduction or elimination of waste wherever possible.

7.4 Factory layout and flow

The physical layout of the factory influences the way it operates and has a great impact on efficiency, productivity and production costs.

A production flow chart is an effective method of visualising the process flow of the factory. A production flow chart graphically represents each stage of the manufacturing process and its relationship and reliance upon the preceding and succeeding activities

The layout of some factories may be outdated or may have been designed without giving consideration to the time it takes to process the product or the cost of the product.

The process flow in the factory should be optimised to ensure efficient operation and reduction or elimination of waste wherever possible. The flow of work through the factory should be managed in a logical order and the available space utilised effectively.

Examples of typical manufacturing operations undertaken in a factory are:

- **Moving:** circulation of materials, components, assemblies and finished products through the factory. Movement should be kept to a minimum as time and cost spent moving items around the factory unnecessarily adds no value to the product
- **Storage:** storage of materials, components, assemblies and finished products. Items may be produced or purchased to order or held as stock. Items should be arranged in a sensible fashion such that they are accessible, easily located and easily picked. The location and quantity of items should be recorded
- **Machining:** processing of materials in the factory in accordance with the specification, ensuring waste is kept at a minimum
- **Counting:** checking and recording quantities against requirements to ensure accuracy and correctness
- **Testing and inspection / Quality Control:** visual and physical checks in accordance with standardised check lists to ensure accuracy and compliance with requirements
- **Scrapping:** discarding of scrap materials left over from the production process that cannot be utilised for any other stage of the manufacturing process. Scrap material should be recycled wherever possible
- **Quarantine:** movement of non-conforming materials, components, assemblies and finished products into a quarantine area for further inspection, return or scrapping
- **Reworking:** where possible making good items that are identified at the inspection stage as non-conforming such that they can be inspected again and returned to the production process providing they are in compliance with the requirements
- **Assembly:** putting together a number of components to create an assembly or unit in accordance with the given specification and requirements
- **Sorting:** arranging items held in stock or for picking at the relevant stage. The categories in to which items are sorted may be based on criteria such as type, specification, application, end use or project for example
- **Loading and transport:** loading the transport vehicle in a logical manner, typically in the reverse order of which they will be erected on site and planning of the most practical route.

Activity

Sketch the layout and flow of your company's production facility

8. Drawing office interface and procedures

8.1 Drawings and specifications

Drawings are an essential part of any manufacturing process or operation.

Drawings and specifications serve as a means of communicating all relevant information with all parties involved in the project.

Clear, concise and detailed drawings should be made available to production and on site to ensure that work is undertaken in accordance with the design and specification as intended. Design and specification information should be issued in advance to all relevant parties such as managers, supervisors, operators, sub-contractors and suppliers.

In addition, it is the drawing office's responsibility to:

- note any unusual details or construction processes with the aim to address specific technical and health and safety issues.
- obtain all external and internal joinery sizes and agree tolerances
- liaise with the Engineer for structural calculations, including mark up and summary drawings
- foreword any cross-sections and layouts which may be of assistance to the engineer with their calculations
- confirm all deviations from the Architect's drawings with the client, in writing. Then highlight any changes on latest drawings
- note any alterations that may involve a cost implication such that the appropriate person can advise the client on any possible change in cost
- carefully read the specification, and inform production as soon as possible of any non-stock or bespoke products and materials.

In general, it is necessary to provide drawings and specifications to:

- the Engineers for their appraisal and sign-off
- the factory to provide manufacturing instructions, scheduling information and control measures
- site to provide scheduling information and instructions for construction

The suite of information should include at least:

- a full and current set of drawings and standard details
- materials list and specification
- fixing schedules/nailing details
    - quantity and centre spacing
    - fixing method
    - fixing specification: dimensions, type, materials, finish/corrosion protection, profile
- manufacturer's instructions and recommendations
- delivery schedules
- check lists as appropriate
- factory drawings:
    - cutting list
    - loading list
    - materials schedules and specification
    - assembly drawings

It is the responsibility of the drawing office to ensure that:

- orders are programmed correctly
- manufacturing drawings are accurate, current and correct
- soleplate and site drawings are accurate, current and correct
- there is effective communication and liaison with the Engineer.

Drawings and specifications serve as a means of communicating all relevant information with all parties involved in the project.

    - work schedule including delivery schedule
    - any special instructions
    - check lists
- Site drawings:
    - foundation drawings
    - soleplate drawings
    - architectural drawings i.e. floor plans, elevations, sections
    - frame erection drawings and standard details
    - material schedules and specifications
    - work scope, sequence and specification
    - delivery schedules
    - any special instructions
    - check lists.

Relevant information should be complete and made available as and when it is necessary.

It is important to ensure that any drawings provided are the current revision and that any drawings that have been superseded are discarded and replaced with the current version. The drawing office must ensure that the latest set of drawings are provided and re-issued if any amendments are made. Subsequent revisions will supersede any earlier issue or duplicate drawings. It is important to check that the drawings which are being worked to are the current and correct set.

Activity

List some of the drawing types for a project in which you are involved and define their purpose

Further reading:

TRADA. The National Structural Timber Specification for Building Construction (NSTS)

8.2 Liaison with engineers

A link should be established between designers, technologists, project manager, and the timber frame engineers and fabrication engineers to ensure that information is communicated effectively and agreed upon and signed off appropriately wherever necessary.

It is important that the drawing office communicate effectively with the timber frame engineer throughout.

Typically, the following drawings and information would be used for communicating information when liaising with the timber frame engineer:

- client project specification
- client architects drawings
- project material lists
- project programme
- soleplate drawings
- floor plans
- cross sections
- elevations
- wall thickness
- joist types/system
- roof construction
- tile weight
- any other relevant information.

8.3 Programming and scheduling

The drawing office should receive a copy of the sales order before proceeding. Schedules can then be drawn up and agreed following communications with the engineer.

Typically working drawings should be completed and provided at least a week prior to delivery. Where this is not possible contracts and production should be informed.

8.3.1 Project planning

It is important that the timber frame manufacturer receives all relevant information simultaneously and that key milestones are agreed prior to commencement such that the timber frame manufacturer is able to plan effectively for:

- design
- engineering
- fabrication
- delivery
- erection.

Reductions in downtime and prevention of delays minimises uncertainty, reduces costs and allows work to be completed in accordance with the overall programme.

8.3.2 Programming orders

The drawing office will receive a copy of the order from the sales department from which a provisional delivery date shall be booked and manufacturing/ production informed.

All working drawings will aim to be produced and complete in sufficient time before delivery wherever possible. If this is not the case then the contracts department and production must be informed as soon as possible.

Once the drawings have been received corresponding records and information must be updated accordingly e.g. job number, client details etc.

8.3.3 Production scheduling

There will be some degree of difference throughout the industry on how production schedules are produced and managed and what form they take but all will have the common goal of maximising capacity at the lowest possible cost and time.

Plant type and layout will also affect how the schedule is prepared and what it contains.

In general production schedules will have specific targets and deadlines which must be achieved otherwise penalties may be incurred.

It is important to be familiar with and be able to accurately interpret all the production schedules across the factory as they may have several layers or levels.

It should be evident from critical path analysis where any bottlenecks are so it is important to ensure that such activities remain as trouble free as possible.

If the factory operates shift patterns and/or handovers then it is important to ensure that the handover brief is clear, concise, easily understood and contains a suitable level of detail. The handover brief should contain a comprehensive review, the current state of the production schedule and any hot spots to be aware of. Poor handovers should not be tolerated and tend to reflect a disordered and careless workforce.

Scheduling is a process that allows the workload to be based upon the real capacity of available resources, for example elements such as:

- equipment and machines
- labour
- tooling
- materials.

However, it is important to bear in mind that the availability of these resources can change rapidly.

Production schedules should be flexible and never set in concrete. Contingencies should be planned for and options assessed from different angles to see if any improvements can be made. Production schedules can be complex to compile and will probably involve computer programmes at some stage during the process. Production schedules may be handwritten, computer generated or a combination of both. While handwritten schedules e.g. on a whiteboard in the factory, are easily accessible and perfectly adequate for displaying pertinent information to personnel, computer generated schedules are more easily adjusted, maintained and managed ensuring that information is current and accurate.

Job tracking may be undertaken in a similar manner either by tracking manually e.g. using a physical job card system or by tracking automatically e.g. electronic barcode or QR code scanning.

8.3.4 Capacity planning

Capacity planning is a key factor as it defines the production capacity of the factory. These are set limits at which products can be manufactured.

The production planning already detailed earlier in the manual using Gantt Charts and PERT Diagrams are helpful for determining the production capacity of the factory but there are many factors that may occur on a daily basis that will change capacity levels.

A good organisation will react quickly to these changes by being flexible enough to cope with whatever is thrown at them in terms of people, plant, downtime, supplies etc.

In the ideal world the order book is full, everyone is competent and knows exactly what they are doing, and are better than their competitors. Also the factory is operating correctly with no faults or breakdowns and running at optimum capacity. However, in the real world this is seldom the case.

Capacity when measured against actual production provides you with the efficiency levels at which you are operating.

These can be represented in many ways but usually in the form of visual methods such as graphs, pie charts or bar diagrams which give a quick visual indicator on the current daily, weekly and monthly production levels.

Activity

Describe how your company go about programming, scheduling and planning

With detailed understanding of the offsite (production) processes and the onsite (erection) processes, the designer can produce optimised timber frame solutions.

8.4 Manufacture and erection

Formal procedures should be in place for checking manufactured items in the factory, during construction and before handover on site.

The designer should be aware of and have a good understanding of the processes involved in manufacture off site and erection on site.

Some of the common stages during manufacture off site and erection on site are given below.

8.4.1 Manufacture (off site operations)

- Cutting and preparing materials
- Assembling panels
- Assembling cassettes
- Assembling modules
- Installation of membranes
- Installation of fire stopping measures
- Preparing components and assemblies
- Installation of services
- Installation of linings
- Installation of sub-assemblies
- Storage (materials, finished assemblies and units)
- Packing and sorting materials
- Loading materials
- Receipt and delivery of goods/ finished items
- Checks and quality control
- Reporting and rectifying errors.

8.4.2 Erection (on site operations)

- Site inspection
- Provision of Services and drainage
- Setting out and laying sole plates
- Erection and management of scaffolding
- Kit checks upon arrival
- Installation of ground floor, where relevant
- Erection of ground floor walls
- Installation of upper floors
- Erection of upper walls
- Erection of roof structure
- Landing and fixing modules
- Provision of protection from moisture before the structure is made weather tight
- External cladding
- Installation of temporary bracing
- Installation of perimeter and partition noggins
- Installation of membranes
- Installation of insulation
- Installation of internal finishes
- Metalwork correctly specified and installed
- Installation of services
- Installation of tie down and restraint straps
- Installation of membranes for moisture control and air tightness
- Installation of fire stopping measures
- Management of plant
- Considerate storage of materials
- Checks and quality control
- Reporting and rectifying errors and repairing damage
- Handover (signatures where necessary)
- Snagging.

8.5 Setting out

The substructure should be correctly set out to receive the timber frame.

The timber frame should be checked to ensure that it is erected accurately in both vertical and horizontal orientations. The load from the frame should be adequately supported. Protection (typically a membrane) should be provided where ledges form moisture traps i.e. where the frame is set back from the supporting structure.

Where the frame overhangs the supporting structure care must be taken to ensure that the overhang is within tolerance.

Activity

Explain the process of setting out

8.6 Specifying soleplates

Soleplates are a critical component of timber frame construction. Soleplates are the first timber components to be installed on site and provide the basis from which the rest of the structure is formed. As well as providing a means to accurately locate the structure soleplates also assist in transferring loads to the foundations.

Material, dimensions and profile of soleplates must be adequate to receive the structure.

Positioning, fixing and level can affect the remainder of the construction process and performance of the completed building. Soleplates should be installed prior to delivery of the timber frame.

A damp proof course (DPC) must be installed between the foundation and soleplate to prevent moisture ingress.

‘Packing out’ of soleplates may be necessary to ensure that the soleplate is level. Packing material must be adequate to support loads applied to the soleplate.

The drawing office must ensure that there is an adequate amount of information to allow the soleplate to be installed accurately and correctly.

The drawing office will produce the soleplate drawing from the architect’s drawings and specification paying particular attention to the following:

- ground floor finish
- wall thickness
- location of any load bearing elements.

The drawings will be passed to the Technical Department for checking where they will be signed and dated. Every drawing that leaves the Drawing Office should leave with the drawing register duly completed.

After checking by the supervisor, any changes must be incorporated before being sent to the client with the standard soleplate letter/ instruction listing any relevant inclusions.

The date on which the soleplate drawings are issued should be recorded appropriately.

Site assembly drawings will typically follow a similar procedure to those of the soleplate drawings but will include all necessary detailed information to allow the frame to be installed accurately and in the correct manner on site.

Activity

Explain why it is important to ensure that soleplates are accurate

8.7 Providing control for manufacture

It is important to ensure that the latest set of drawings is referred to as these will supersede any earlier issue or any duplicate drawings. Superseded drawings should be replaced with the current drawings and any relevant notes made upon the superseded drawings should be transferred to the current drawings as appropriate.

All internal and external joinery sizes must be obtained and clearly defined.

It is important to liaise with the engineer for structural calculations as necessary. Notes which might aid the engineer with such calculations should be made to any drawings as appropriate.

All deviations from the architect's drawings must be confirmed with the client in writing. All changes must be clearly highlighted on a separate record sheet and indicate when and with whom the changes were agreed.

Any alterations which are likely to have any cost implications must be noted such that the appropriate person can advise the client on any possible change to costs.

It is important to ensure that the specification has been read thoroughly and understood. Where necessary the appropriate person should be informed in the earliest instance about the inclusion of any non-stock, non-standard, special or long lead items and/or material.

Once working drawings have been completed they should be submitted alongside the panel drawings to the Technical Department for checking. At this stage a set of drawings should also be issued to the client with the 'Preliminary' letter for their information. Once the drawings have been checked by the relevant supervisor(s) all amendments as advised should be made and the drawings up-revised. At this stage the calculations and finalised drawings should be issued to the client.

8.8 Working drawings and information

All working drawings must be precise, accurate and unambiguous. They should carry all relevant information as necessary.

Once the working drawings have been completed a full set should be produced for the relevant supervisor(s) to check.

Every drawing that is sent to the supervisor(s) must be signed or initialled and dated.

A set should also be sent to the client with 'PRELIMINARY' or equivalent marked on the covering letter for their information and to provide an opportunity to check it.

After checking by the relevant supervisor(s) any changes should be completed before release.

A final set of drawings together with any calculations can now be sent to the in-house distribution list plus those outside including a client's pack.

Every drawing that leaves the Drawing Office should be entered into a formal register.

8.8.1 Production drawings

Production drawings must be precise, accurate and unambiguous. They should state descriptions, specification and/or references, dimensions, special conditions and exact quantities or amounts of materials to be used, loaded and/or processed.

Production drawings must be precise, accurate and unambiguous.

When working with production drawings it is important to ensure they have been signed/initialled and dated by the person who is responsible for having produced them. This could also include anything produced by external people or companies who are not directly employed by the timber frame manufacturer.

Typically, production drawings will have a check box or equivalent system of approval/sign-off for each of the relevant people to sign and/or initial to confirm that they have checked, understood and adhered to the drawings. The current date should also be added to the drawings upon providing a signature and/or initials.

The drawing office should then check that all the details on the production drawings and corresponding cutting and loading lists are accurate and correct before issuing.

Typically, job completion will be recorded and dated in the contract book or equivalent.

It is important to ensure that a full set of the latest revisions of the drawings and erection instructions are issued to site alongside the timber frame kit.

Typically, these will include, but shall not be exclusive to:

- soleplate drawings
- timber frame drawings
- timber frame detail book
- fixing schedules
- erection checklist
- component and delivery schedules
- agreed work scope and specification.

8.8.2 Cutting lists

A cutting list is a detailed list which specifies the material that is to be selected and how it is to be processed.

Careful consideration and effort must be made when producing cutting lists to ensure that material is used economically such that any waste is minimised or reused wherever possible.

Cutting lists must be precise, accurate and unambiguous. They should state descriptions, specifications and/or references, dimensions, special conditions and exact quantities or amounts of materials to be processed. It may be necessary to provide drawings or diagrams to effectively communicate information.

As is the case with production drawings, when working with cutting lists it is important to ensure they have been signed/initialled and dated by the person who is responsible for having produced them. This could also include anything produced by external people or companies who are not directly employed by the timber frame manufacturer.

It is common for cutting lists to have a check box or equivalent system of approval/sign-off for each of the relevant people to sign and/or initial to confirm that they have checked, understood and adhered to the list. The current date should also be added to the cutting list upon providing a signature and/or initials.

Cutting lists may be generated by a computer system from the designed timber frame building. The project is separated into fabricated items and loose components. The computer system then collates all the component information into groups of items (for example panels of each level) and outputs the cutting list to present all the plates, studs, lintels, sheathing etc. in a form that manufacturers can select from their timber stock.

The cutting files generated from the computer also has the ability to be electronically transferred to computer aided manufacture (CAM) that can cut components accordingly.

8.8.3 Loading lists

A loading list is a detailed list which specifies the material that is to be loaded.

Loading lists must be precise, accurate and unambiguous. They should state descriptions, specifications and/or references, dimensions, special conditions and exact quantities or amounts of materials to be loaded.

As is the case with production drawings and cutting lists, when working with loading lists it is important to ensure they have been signed/initialled and dated by the person who is responsible for having produced them. This could also include anything produced by external persons or companies who are not directly employed by the timber frame manufacturer.

It is common for loading lists to have a check box or equivalent system of approval/sign-off for each of the relevant people to sign and/or initial to confirm that they have checked, understood and adhered to the list. The current date should also be added to the loading list upon providing a signature and/or initials.

Activity

Set out below, or on a separate sheet, the sequence of the design

Ensure a full drawing packages, details, erection instructions, nailing schedules, health and safety plan and build sequence are issued 2 weeks before the timber kit work starts.

9. From the Soleplate to the Roof

9.1 Processes

When erecting timber frame buildings the erectors will follow a pre-defined method of construction and series of processes from the soleplate upwards. It is fundamental to have an understanding and working knowledge of these processes.

Activity

Under the following headings list at least three main items which are relevant to your company and which you consider to be the most important to expect and look out for at each stage

2 weeks before work starts

1.) ______________________________

2.) ______________________________

3.) ______________________________

1 week before kit delivery

1.) ______________________________

2.) ______________________________

3.) ______________________________

Upon delivery

1.) ______________________________

2.) ______________________________

3.) ______________________________

Further reading

STA Advice Note 4.2: Soleplate tolerances

STA Advice Note 10: Timber Stud Frame Separating Walls

http://www.structuraltimber.co.uk/library

TRADA. Timber frame construction: designing for high performance (5th edition)

Storage

1.) ______________________________

2.) ______________________________

3.) ______________________________

During site erection

1.) ______________________________

2.) ______________________________

3.) ______________________________

Frame checks on completion of erection

1.) ______________________________

2.) ______________________________

3.) ______________________________

Wall checks on completion of erection

1.) ______________________________

2.) ______________________________

3.) ______________________________

Floor checks on completion of erection

1.) ______________________________

2.) ______________________________

3.) ______________________________

Roof checks on completion of erection

1.) ______________________________

2.) ______________________________

3.) ______________________________

9.2 What you should look for

Below are the main items, activities and operations which you should be looking for throughout the construction process, some of which you may have already considered and included above.

The following checklist will serve and help you to understand how the work can be divided into manageable and meaningful blocks as the building takes shape

2 weeks before work starts:

1) a full drawing package
2) detail booklet and erection instructions
3) nailing schedule
4) health and safety plan
5) reviewed plans and established build methodology
6) pre-start meeting completed
7) cranage and scaffolding agreed
8) agreed build programme.

1 week before kit delivery:

1) foundations constructed correctly using setting out drawings
2) foundations are level
3) foundations are square and check diagonals
4) foundations are dimensionally correct
5) problems reported and rectified
6) scaffolding completed
7) access available
8) crane hard standing agreed
9) plant to offload available
10) storage space available.

Upon delivery:

1) check all components delivered
2) check for damage to kit
3) report any shortages/damage
4) sign for goods received.

Storage:

1) keep materials off the ground
2) store panels flat with sheathing side up
3) keep trusses vertical on bearers at node points or flat on adequate bearing
4) keep materials under cover but maintain ventilation

During site erection:

1) care is taken to avoid damage
2) follow drawings and details
3) temporary bracing is fitted
4) floors are not overloaded by materials
5) safe systems of work are implemented
6) panels are correctly nailed and secured
7) work is progressed systematically, floor-by-floor
8) tidy up as you go
9) all work is completed per level
10) scaffolding progresses well ahead and safely.

Frame checks on completion of erection:

1) frame anchored to slab
2) all damage repaired
3) cavities plumbed to suit external cladding and cavity width
4) structural shell handed over and signed for.

Wall checks on completion of erection:

1) DPC's are under ALL ground floor walls in contact with slab
2) panels are right way up, in correct position and plumb to tolerance
3) all joints are tight
4) all fixings are as per schedule.

Floor checks on completion of erection:

1) joists in accordance with design drawings
2) joists have adequate bearing
3) joists are correctly nogged or blocked out
4) joists nailed with tight connections as per schedule
5) joists are tight and even
6) stair trimmed correctly
7) notching or drillings ONLY as per detail
8) joist hangers fully nailed
9) no excessive loads applied, i.e. plasterboard stacks, etc.

Roof checks on completion of erection:

1) trusses correct spacing and plumb to tolerance
2) all trusses have clips fitted to wall head
3) trusses are correctly braced
4) loose infill tight and well connected
5) girder trusses are bolted or well nailed
6) multiple studs fitted under point loads
7) locating plate and head binder plate fitted if required
8) soffit supported with noggings, if required
9) valley boarding fitted
10) ladder sections connected to spandrel panels
11) roof bracing connected to spandrel panels
12) all shoe ironmongery fitted and fully nailed.

10. Multi-Storey Timber Frame Buildings

10.1 Overview

This section highlights the main points you should be concerned with when faced with the design, manufacture and erection of multi-storey buildings.

In timber frame construction, four or more storeys is considered multi-storey construction.

As a result of technological progress, the use of innovative materials and systems and the application of increasingly modern and refined processes, timber frame structures are rising higher and higher.

Timber frame construction lends itself well to multi-storey construction and provides five proven benefits:

- Supply
    - proven supply chain
    - design and build solutions
- Reduced support loads
    - ground works
    - transfer slabs
    - foundations
- Quality
    - factory standards
    - site build improvements
- Sustainability
    - reduced environmental footprint
    - renewable resource
    - reduced waste
    - reduced impact on the local community
- Speed of erection
    - offsite manufacture.

Activity

List some other benefits of timber frame where multi-storey construction is concerned

10.2 Factors to note

10.2.1 Weight

The higher the building the greater the load placed on the lower storey walls. Therefore, larger studs will be required than for low-rise buildings, or studs may be placed at closer centres.

10.2.2 Wind and weather

Wind speeds increase with height so the lateral load is increased the higher the building which can mean the sheathing needs to be different, and will usually be either thicker or a closer nailing schedule to the sheathing will be required.

Other considerations due to wind and weather:

- internal walls and compartment walls may also require sheathing
- plasterboard or similar linings will also contribute to the stability
- roof uplift increases and greater holding down may be required.

Note, the above is also true for timber frame buildings in high exposed areas or of narrow frame design.

10.2.3 Condensation

Where thicker sheathing is used, condensation risk may increase and must be taken into consideration and checked.

10.2.4 Disproportionate collapse

Disproportionate collapse is a structural building failure, caused by an external force, in which the building is not proportionally damaged, that is some areas are more damaged than others. The structure not directly affected by the accident must not collapse significantly in response to the nature of it.

The calculations for multi-storey construction, as you would expect, are very different to normal and the structural engineer will provide details on the design requirements in the event of accidental damage to the building.

The designer should be familiar with the effects of wind loads on the building and any special requirements to resist disproportionate collapse.

Disproportionate collapse affects the building design and calculations to prevent it need to be incorporated into the timber frame design package. To design for disproportionate collapse prevention, the building robustness in accidental events must be ensured in the structural design. This is achieved by calculations for accidental events, such as earthquakes or explosions, which may affect the specific building. These calculations are done individually for every building and are therefore termed case-specific.

Disproportional collapse must be prevented by design in accordance with British Standards and STA guidance (or different standards applicable at the time of reading this document), as part of the accidental design situations. Disproportionate collapse is a critical consideration for multi-storey buildings above 4 storeys and for schools of 2 storeys and above.

10.2.5 Differential movement

As the timber frame dries it shrinks and the overall height reduces resulting in differential movement between the timber frame and other parts of the structure. The extent of differential movement becomes greater as the number of storeys increases.

Changes to gaps around windows, different types of wall ties, low moisture timber used at appropriate locations and adjustments to staircases will all be affected. In addition, other composite materials may have to be fitted to compensate for the movement.

The magnitude of differential movement increases as the structure increases in height - that is higher structures such as those of multi-storey construction will have a greater degree of differential movement as you travel up the structure.

For multi-storey structures you will have additional safety hazards to control so make sure your Risk Assessments are adequate and well understood by your team.

Activity

List some locations of a multi-storey building which are most susceptible to differential movement

10.2.6 Manufacture

You and your team could well be faced with many different techniques when manufacturing multi-storey buildings. They require and demand much more accuracy and care.

Any mistakes and errors become amplified the higher the building.

10.2.7 Build tolerances

Multi-storey timber frame structures, you will probably find, require a different set of tolerances to the normal domestic requirements and you must be aware of them at the outset. Two main reasons being to avoid conflict with lift shafts and cladding cavity issues within the building.

Sufficient guidance on tolerances is readily available for buildings that are less than four storeys high for which you should be familiar. However, when working on buildings above four storeys, additional considerations are necessary and you must make yourself aware of these requirements before you commence site erection.

You are strongly advised to go through the construction notes checklist and tolerances supplied by the manufacturer for the following key areas of the building:

Further reading:

STA Advice Note 4.3: Timber Frame Wall Tolerances

http://www.structuraltimber.co.uk/library

- support structure / foundations
- soleplates or bottom rails of panels where there are no soleplates
- fixing down of sole plates or bottom rails of wall panels where there are no soleplates
- walls
- floors.

10.2.8 Safety and construction procedures

As always, the regulations require that a risk assessment of the method of construction is undertaken. For multi-storey structures you will have additional safety hazards to control so make sure your Risk Assessments are adequate and well understood by your team.

The following key areas will be covered by the timber frame design and build team:

- description of the Project
- description of the environment and access requirements
- description of the design, including design loads and a breakdown of components
- Method Statements of the construction process to erect the Timber Frame and associated components
- Risk Assessments with control measures on how the information is passed to site operatives
- the role of each company involved with the names of those responsible for supervising and overall responsibility.

10.2.9 Fire safety

As with any multi-storey building, one of the most important factors is its ability to withstand a major fire.

With this in mind the following requirements have been accepted as the norm across the UK.

Fire safety specifications change when the building's lowest ground level to top floor deck height measurement exceeds 18 metres. It is vital to read and understand the relevant regulations and standards to ensure that you are familiar with, and have a good working knowledge of them.

10.3 Summary

This section aims to reiterate and summarise some of the most important points concerning multi-storey timber frame construction.

Additional considerations are:

- weight
- wind and weather
- condensation
- disproportionate collapse
- differential movement.

Five proven benefits for the multi storey construction market are:

- supply
- reduced support loads
- quality
- sustainability
- speed of construction.

Tolerances - You must go through the construction notes checklist and tolerances supplied by the manufacturer for the following key areas of the building:

- support structure / foundations
- soleplates or bottom rails of panels where there are no soleplates
- fixing down of sole plates or bottom rails of wall panels where there are no soleplates
- walls
- floors.

Workmanship - You and your team will be faced with many different techniques when erecting multi-storey buildings. They require and demand much more accuracy and care.

Always bear in mind that any mistakes and errors become more amplified the higher the building.

Site Considerations - Ensuring that sufficient training is in place to understand the construction methods and processes.

Site management is especially important to cover the information flows and ensure that the logistics of the site can cope with the speed of the offsite assembled units.

Identification and agreement across all parties in the project of tolerance issues such as foundation levels.

Integration and method of build knowledge to the follow-on trades to the timber frame such as plasterboard fixers and service trades.

Activity

Do some research and give some examples of timber frame medium-rise multi-storey buildings in the UK. Give a brief overview of each and include information such as location, method of construction, materials and systems used etc.

11. Joists

11.1 Overview

There are a broad variety of joist types and systems available, all of which have different properties, characteristics, benefits and features, but which will have been appropriately selected to satisfy the requirements of the floor, walls and roofs that are to be manufactured.

11.2 Benefits of joist systems

One of the advantages of timber frame is it's a lightweight construction material. A reduction in weight without sacrificing structural performance furthermore adds to its appeal.

There are several joist types and systems which provide an alternative to solid timber joists on the market today. Selecting the appropriate joist type or system may depend upon a number of factors such as their suitability for certain applications, cost, aesthetics, ease of installation, structural performance, dimensions and permissible span, among others.

Naturally, as well as offering a variety of benefits there may also be cost and supply implications which should be investigated in addition to any design considerations prior to selecting the most appropriate products and systems.

Joists are typically spaced at 400 or 600mm centres to conform to standard dimensions of common sheathing and lining materials. Joist centres can be reduced or individual joists can be assembled to make a multiple member to allow for increased loading or floor spans as necessary.

I-joists provide reduction in weight without sacrificing structural performance.

Activity

Describe what you think are the main purposes of joists?

11.3 Solid timber joists

Solid timber joists have been used traditionally for the construction of floors though nowadays there are many alternatives available such as I-joists and open web joists, the details of which are outlined below.

Some of the main features and benefits of solid timber joists are as follows:

- solid timber joists are traditional and as such a familiar product which people are comfortable working with and have experience working with
- solid timber for structural use is strength graded
- performance values are available for solid timber for structural use
- solid timber joists can be cut, processed and worked by traditional tools and methods both in the factory and on site
- solid timber can be finger jointed to produce lengths longer than can be 'naturally' produced
- solid timber is easily treated with preservative, water repellent and fire retardant treatments.

Some of the reasons why I-joists and open web joists may be selected instead of solid timber joists are given below.

11.4 I-joists

An I-joist is a composite engineered timber joist of a similar cross section profile to steel I-beams and typically comprises solid timber or Engineered Wood Product (EWP), most typically laminated veneer lumber (LVL), top and bottom flanges bonded in parallel to a web of wood panel material such as OSB or hardboard though I-joists with corrugated steel, LVL or solid timber webs are available yet less common. The web is typically inserted into grooves in both flanges and glued.

I-joists are typically used as joists, studs and rafters for floor, wall and roof applications. I-joists can be used for domestic, commercial and industrial applications.

I-joists may be used as a core component of floor cassettes, wall panels and roof cassettes assembled offsite.

There are several I-joist systems available produced by different manufacturers.

11.4.1 Main features and benefits of I-joists

Some of the main features and benefits of I-joists are as follows:

- manufacturers offer a range of standard section sizes similar to typical solid timber section sizes. Typically, a range of standard approved connectors and solid EWP members are also available to suit standard I-joist section sizes
- I-joists typically weigh less than solid timber members of an equivalent section size and so have an excellent strength to weight ratio
- I-joists are versatile and can be designed and used effectively for wall, floor and roof applications
- I-joists are typically simple to install, potentially resulting in increased time savings and reduced labour costs
- holes can be readily created in the web for accommodation of services
- span tables, performance values, standard construction details, specification and installation guides are provided in the manufacturer's literature
- I-joists are manufactured offsite ensuring consistent quality, reliability and uniformity and are dimensionally stable and

will resist distortion such as shrinking and warping providing the manufacturer's literature is adhered to

- I-joists form part of a system and are complimented with solid EWP of similar section sizes for use as elements such as trimmers and rim board, among others
- I-joists are typically cut to length in the factory, reducing waste and negating the need to cut on site
- I-joist manufacturers provide design software, training and support specifically for their joist system
- I-joists are available in long lengths allowing for long clear spans thus speeding up construction by eliminating the need to lap joists over bearing walls or supporting beams.

11.4.2 Installation of I-joists

I-Joists are generally simple and straightforward to install for several reasons:

- as above, I-joists are typically cut to length in the factory in accordance with the corresponding design and specification, negating the need to cut to length on site
- I-joists are typically delivered to site in packs alongside the corresponding components, drawings and specifications and ready to install. Typically, the components will be marked with a unique reference which correspond with those on the drawings
- I-joists are installed in accordance with the manufacturer's literature and the corresponding drawings and specifications provided
- I-joists can be worked and fastened with traditional framing tools and fasteners with no requirement for special tools
- where necessary positions along the I-joist can be reinforced using backer blocks at locations of incoming members and/or web stiffeners at location of bearing/support. Backer blocks and web stiffeners are typically plywood
- I-joists can be fixed together to create multi-ply members for enhanced performance
- I-joists must be correctly braced before they can be used as a working platform.

The manufacturer's literature, drawings and specifications should always be referred to or the manufacturer's technical support be contacted for guidance if in any doubt.

11.4.3 Cutting and holing I-joists

Holes can be made in I-joist webs to accommodate services such as electrical wiring, plumbing and ductwork. However, the allowable cutting and holing areas must be carefully observed, in accordance with the engineer's calculations.

Typically, the web will be manufactured with a number of pre-punched knock-outs at regular centres along its length which can be knocked out with a hammer, thus eliminating the need for a saw. Holes can be carefully cut or drilled at locations other than the knock-outs but the manufacturer's literature must be adhered to so as not to reduce the performance of the member by cutting holes that are too large and/or positioned too closely to one another, to the edges and ends of the web, bearing/supports, incoming members and/or cantilevers.

Metalwork is available which allows for larger holes to be cut in webs to accommodate larger services such as HVAC or cable trays.

The manufacturer's literature, drawings and specifications should always be referred to or the manufacturer's technical support contacted for guidance if in doubt.

11.4.4 Precautions

There are several important precautions to bear in mind when using I-joists:

- other than cutting to length I-joist flanges should never be cut, drilled, hammered or notched
- I-joists must not be supported upon their web
- when creating holes in the webs the manufacturer's literature must be adhered to. Holes should not be hammered in to the web unless at pre-punched knock out locations where they are provided
- concentrated loads should be applied to the top surface of the top flange or with the provision of suitable connectors only. Under no circumstances should a concentrated load be suspended from the bottom flange. The only exception may be very light loads such as light fixtures or ceiling fans
- I-joists must not be used in applications where they will be permanently exposed to weather or areas of high humidity
- I-joists must be correctly braced before being used as a working platform
- non-approved connectors must not be used.

The manufacturer's literature, drawings and specifications should always be referred to or the manufacturer's technical support be contacted for guidance if in any doubt.

11.4.5 Storing and handling I-joists

There are several points to bear in mind when handling and storing I-joists:

- I-joists must be protected from the elements and kept dry. Packs should be stored indoors where practical and covered at all times
- packs must be kept level and off the ground using bearers positioned at regular centres
- packs must be separated from one another using bearers positioned at regular centres
- I-joists must not be dropped or subjected to heavy impact
- I-joists must be stored, lifted and transported on their edge, not on their flat
- I-joists must not be lifted by their top flange.

11.5 Open web joists

An open web beam is a composite engineered joist and typically comprises solid timber top and bottom chords plated together in parallel with punched metal webs pressed into the chords, though open web beams with timber webs plated to the top and bottom chords or similar are available yet less common.

Open web beams are typically used as joists, studs and rafters for floor, wall and roof applications. Open web beams can be used for domestic, commercial and industrial applications.

Open web beams may be used as a core component of floor cassettes, wall panels and roof cassettes assembled offsite.

There are several Open Web Beam systems available produced by different manufacturers.

Open web joist in showroom roof structure

Open web joist in factory shop floor

Open web beams and I-joists share a number of advantages.

11.5.1 Main features and benefits of Open web joists

Some of the main features and benefits of open web beams are as follows:

- manufacturer's offer a range of standard section sizes similar to typical solid timber section sizes. Typically, a range of standard approved connectors and solid EWP members are also available to suit standard open web beam section sizes
- open web beams typically weigh less than solid timber members of an equivalent section size and so have an excellent strength to weight ratio
- open web beams are versatile and can be designed and used effectively for wall, floor and roof applications
- open web beams are typically simple to install, potentially resulting in increased time savings and reduced labour costs
- open web beams have large openings between the chords and allow for easy installation of services in the voids without the need to cut, notch or drill
- open web beams offer flexibility at the design stage as the webs can be positioned to suit particular applications and conditions and reinforcement can be incorporated to enhance performance where necessary
- span tables, performance values, standard construction details, specification and installation guides are provided in the manufacturer's literature
- open web beams are manufactured offsite ensuring consistent quality, reliability and uniformity and are dimensionally stable providing the manufacturer's literature is adhered to
- open web beams form part of a system and are complimented with solid EWP or solid timber of similar section sizes for use as elements such as trimmers and rim board among others
- open web beams are manufactured to length, reducing waste and negating the need to cut on site
- open web beam manufacturers provide design software, training and support specifically for their joist system
- open web beams are available in long lengths allowing for long clear spans thus speeding up construction by eliminating the need to lap joists over bearing walls or supporting beams.

11.5.2 Installation of open web joists

Open web beams are generally simple and straightforward to install for several reasons:

- open web beams are manufactured to length and designed for specific applications in accordance with the relevant specification negating the need to cut to length or modify on site
- open web beams may have a trimmable 'horn' at each end to make minor adjustments on-site to accommodate dimensional tolerance between supports
- open web beams are typically delivered to site in packs alongside the corresponding components, drawings and specifications and ready to install. Typically, the components will be marked with a unique reference number which correspond with those on the drawings
- open web beams are designed to be installed in a specific orientation. It is important to ensure that the beam is installed with the top chord to the top

- open web beams are installed in accordance with the manufacturer's literature and the corresponding drawings and specifications as provided
- open web beams can be fastened together to create multi-ply members for enhanced performance
- open web beams must be correctly braced before they can be used as a working platform.

The manufacturer's literature, drawings and specifications should always be referred to or the manufacturer's technical support be contacted for guidance if in any doubt.

11.5.3 Installation of services

Services can be readily installed in the voids between the top and bottom chords without the need for cutting notching or drilling.

The manufacturer's literature, drawings and specifications should always be referred to or the manufacturer's technical support be contacted for guidance if in any doubt.

11.5.4 Precautions

There are several important precautions to bear in mind when using open web beams:

- holes and/or notches must not be or cut or drilled into the timber chords
- the timber chords must not be cut
- the webs must not be cut, modified or removed
- open web beams must not be used in applications where they will be permanently exposed to weather or areas of high humidity
- open web beams must be correctly braced before being used as a working platform
- non-approved connectors must not be used
- open web beams must be installed in the correct orientation.

The manufacturer's literature, drawings and specifications should always be referred to or the manufacturer's technical support be contacted for guidance if in any doubt.

11.5.5 Storing and handling open web joists

There are several points to bear in mind when handling and storing open web beams:

- open web beams must be protected from the elements and kept dry. Packs should be stored indoors where practical and covered at all times. Storage time prior to installation must be kept to a minimum
- packs must be kept level and off the ground using bearers positioned at regular centres
- packs must be separated from one another using bearers positioned at regular centres
- open web beams must not be dropped or subjected to heavy impact
- open web beams must be stored, lifted and transported on their edge, not on their flat
- where slings are used to lift Open web beams these should be fabric.

11.6 Engineered wood products in floors

Engineered wood products (EWP) such as LVL, Glulam or PSL may be used in conjunction with I-joists and Open web joists at locations where heavy loads are to be carried/transferred e.g. trimmers or posts/columns or for long unsupported spans. EWP such as LVL is typically used for rim boards at the perimeter of the floor.

Activity

Why might you specify I-joists or open web joists rather than solid timber joists?

11.7 Structural deck

A structural deck is fixed to the top of the joists in accordance with the manufacturer's instructions to provide rigidity, stability and lateral restraint to the floor joists and ultimately create a safe platform.

11.8 Bracing

Floor joists should be adequately braced in accordance with the manufacturer's instructions to provide lateral stability until the floor deck is fully installed. The floor bracing is gradually removed as the structural deck is installed.

11.9 Perimeter and partition noggins

Perimeter noggings, also commonly referred to as noggins or dwangs are short lengths of timber or EWP installed between the joists at locations around the perimeter of the floor to support the edge of the structural deck and provide some lateral stability, though these should not be relied upon in lieu of floor bracing.

Partition noggings, noggins or dwangs are short length of timber or EWP installed between the joists at the appropriate locations and at regular centres to support partitions installed above on the structural deck.

11.10 Floor connectors and restraint straps

A large and varied range of connectors and restraint straps are available to cover the majority of connection details typically found within a floor and to provide restraint to the walls.

12. Roof construction

12.1 Overview

Traditionally, roofs were constructed by skilled carpenters using timber to form rafters, purlins, ceiling joists, binders, hips and suchlike. Roofs of this type are generally known as 'site cut' or 'loose rafter.' They usually rely on internal loadbearing walls to provide additional support, although in some cases the timbers may be joined together to form trusses which are positioned at fairly wide centres to support the timbers between them. The roof structure should provide lateral restraint to the walls and be capable of resisting the forces imposed upon it.

Design considerations to meet fire, thermal and acoustic requirements are described in more detail in other sections of this workbook.

12.2 Typical roofscapes

Below are some examples of typical roofscapes, though some are more common than others. You may be most familiar with duopitch and hipped roofs.

- Duopitch
- Hipped
- 'L' return
- 'T' intersection
- Dormer
- Dogleg
- Monopitch
- Overlaid hip
- Gablet
- Dutch or barn hip
- Mono 'L' return / hip

Activity

List and sketch the different types of roof on buildings either currently being designed in your office or designed recently

12.3 Cold and warm pitched roof construction

Warm roof and cold roof construction are two different methods of insulating the roof space.

12.3.1 Cold pitched roof construction

In general, the insulation is located at ceiling level. A cold roof may be ventilated or non-ventilated.

12.3.2 Warm pitched roof construction

In general, the insulation is located at rafter level. A warm roof may be ventilated or non-ventilated. This is most common where the roof space provides additional living space.

Activity

Sketch cross sections of both a typical warm and cold pitched roof, including labels for each of the components

12.4 Trussed rafters

During the 1960s the punched metal plate connector, or truss plate, was developed. A punched metal plate is essentially a piece of thin galvanised steel sheet which is punched through to form an array of teeth.

Modern trussed rafters are individually designed prefabricated structural components made from strength-graded timber members of the same thickness, joined together with punched metal plate connectors. Metal plate connectors would be considered semi-rigid; however, there are different forms of systems that can be formed from stiff glued joints to pinned bolted connections depending on the structural use and available fabrication methods.

Individual trusses and entire roofs are designed using bespoke design software and commonly manufactured in a factory, produced consistently in multiples.

Trusses provide a structural framework to support the roof fabric of building, room ceilings and, in some cases, floors. They are generally spaced at 600mm centres or less, replacing the 'common rafter' in a traditional or 'cut' roof, hence the term 'trussed rafter.'

In addition to roof systems, trusses can be formed to act as support to floors, scaffolding systems, bridges and overhead gantries. Truss systems can also be used to provide bracing and stability in both the horizontal and vertical plane in shear wall systems for example. Roof trusses (also referred to as trussed rafters) are the most commonly used method for forming the roof structure.

Designed in almost any shape or size, roof trusses provide a rigid strong framework that will carry the load of a roof to the outside walls and withstand external forces such as wind and snow loads.

The structural design of trusses is typically the responsibility of the punched metal plate manufacturer, whereas it is the responsibility of the building engineer to ensure the overall stability of the roof and to advise the truss manufacturer of the type and weight of roof finish, any special features and suchlike. Likewise, the building designer is responsible for designing and detailing all elements of roof bracing but it is practical for the truss manufacturer to include the bracing design in accordance with the requirements, or for it to be designed by a structural engineer.

A typical roof truss comprises a bottom chord, top chords and webs, joined with punched metal connector plates.

Trusses are typically delivered to site as prefabricated components and installed on to the wall plates at regular centres. The roof structure may be constructed at ground level and craned in to position on top of the upper storey walls.

Once the trusses are installed on the wall head lateral stability is provided by the installation of timber lateral bracing.

A large variety of truss types are available covering a wide range of roof structures and building types. Some truss types are more common than others, but it is important to be familiar with available truss types and understand the purpose of each.

Trusses should never be cut or modified on site without the truss manufacturer's approval.

Some of the most common types of trusses are as follows:

- **Fink:** the most common truss design
- **Queen post:** most commonly used for garages
- **King post:** used for small span applications
- **Mono:** most commonly used for hip ends and porches
- **Raised tie mono:** may be used 'back to back' with a parallel chord truss to create high ceilings
- **Parallel chord / beam:** girder versions (multiple members) are capable of supporting high loads over large spans
- **Scissor:** used for sloping ceiling designs
- **Howe:** most commonly used to support other trusses
- **Attic frame:** offers additional space. Attention must be paid to regulations on access and emergency escape. Overall height may cause transport problems
- **Fan:** sometimes used when a smaller rafter size is required than a fink can't provide
- **Double W:** most commonly used for long spans
- **Hip:** used in hip ends and flat roofs
- **Half hip:** used to form mono pitch hip ends
- **Valley frames:** reduced frames to marry one roof in to another
- **Asymmetric:** useful where there is an elevation to match, but the maximum truss height is restricted
- **Short cantilever:** a relief rafter may be added
- **Long cantilever:** cantilever webs are usually included
- **Bobtail / stub end:** truss designed with one end cut back
- **Top hat:** due to transport height restrictions the truss is supplied as a base truss and a capping frame
- **Raised tie / collar:** height of the ceiling may be limited due to a combination of span, pitch and roof loading
- **Vaulted ceiling:** a slightly more flexible alternative design for a raised ceiling
- **Bowstring / barrel vault:** typically used with metal sheeting systems
- **Pagoda:** the pitch of the roof becomes steeper
- **Stepped ceiling:** allows for more light to be available
- **Combination:** combination of profiles for different design details on either elevation
- **Specials:** bespoke design to suit a large range of special requirements.

Activity

Sketch some common truss profiles and label each of their components

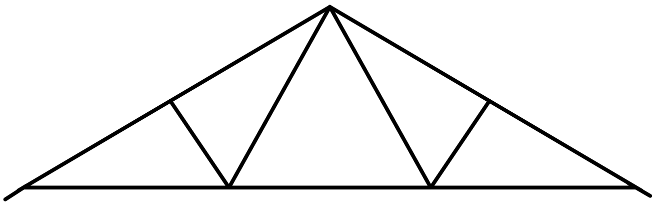
The key benefits of trussed rafter roofs are:

- trusses are most commonly manufactured in a factory and so produced in controlled conditions, ensuring greater consistency
- there is a great deal of flexibility in the shapes of trusses
- the manner in which trusses are designed and manufactured enables the production of a wide variety of roofscapes
- site fabrication and installation time is significantly reduced and the requirement for skilled labour is reduced
- when compared with a traditional site-cut roof, up to 40% less timber is used
- in the majority of cases, no internal supports are required thus giving much greater freedom with room layouts
- the bottom chord of a truss can be designed to act as a floor joist to form attic trusses to produce a 'room in the roof'
- the majority of domestic roofs and a large number of commercial roofs in the UK are now constructed using trusses.

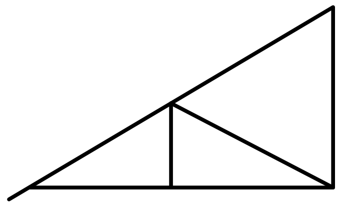
12.5 Triangulated and non-triangulated trusses

Most of the trusses described above are defined structurally as triangulated. This results in the principle forces in the members being either axial tension or compression. The only bending moments applied to the members are due to loading i.e. from the tiles, between the joints. Since timber is good at resisting tension and compression applied parallel to the grain, the resulting members of the truss are relatively small and slender. The triangulated truss also has a good resistance to deflection as it doesn't rely on the elastic stiffness of the timber alone.

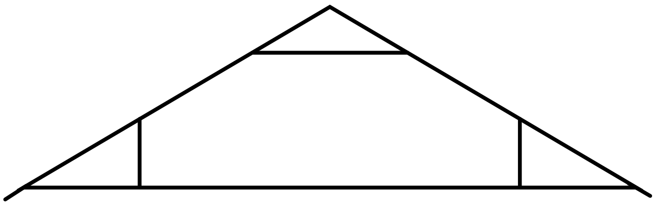
With non-triangulated trusses, such as the attic truss the members are subject to a much greater proportion of bending stress which results in larger timber sizes even taking into account the increased load from a floor. For example, rather than a typical 35 x 97mm member in a triangulated truss, members with a cross section as large as 47 x 197mm may be required for similar clear spans.



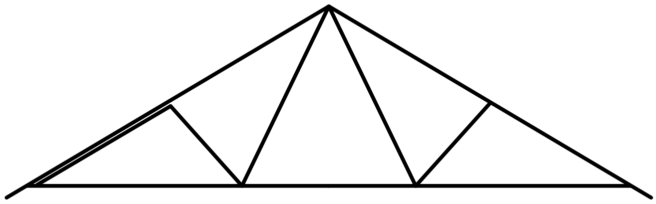
FINK



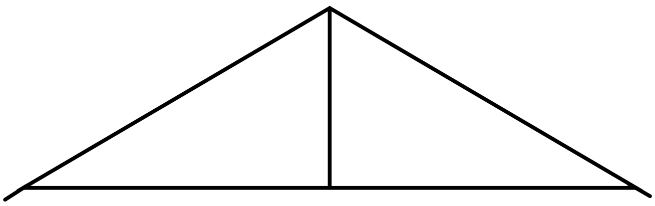
MONO



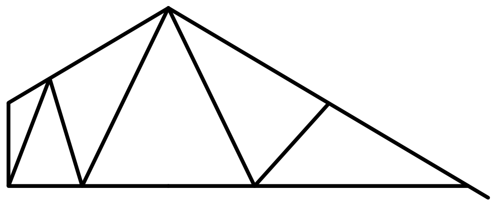
ATTIC FRAME



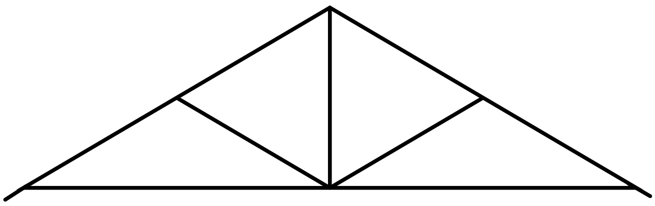
SHORT CANTILEVER



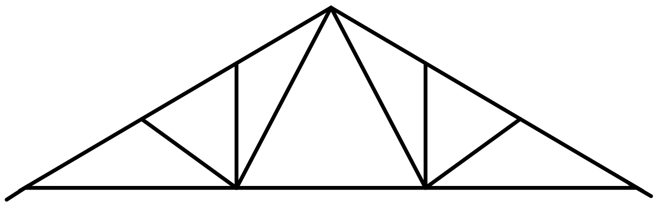
KING POST



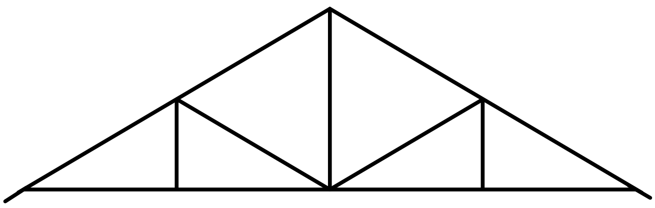
BOBTAIL / STUD END



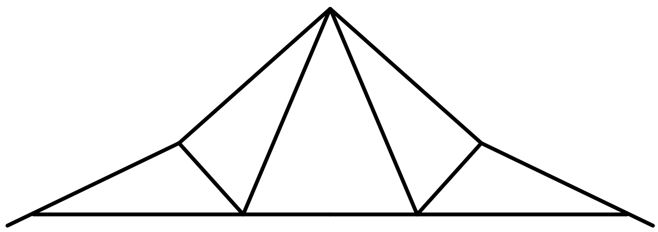
QUEEN POST



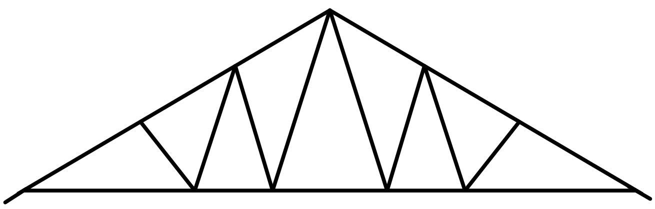
FAN



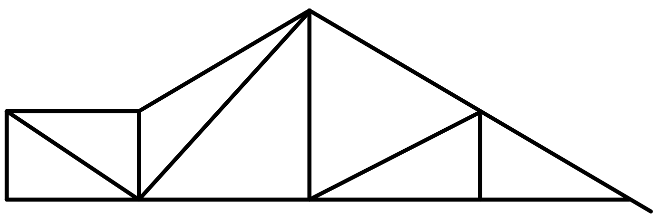
HOWE



PAGODA



DOUBLE W



COMBINATION

12.6 Raised tie roofs

A raised tie roof is one where the ceiling joists are higher than the external walls.

Where trusses are used, since it is a non- triangulated truss, the members are subject to higher bending moments and consequently larger members are required. Since commonly available solid timber is limited to around 47 x 222mm this in practice limits the horizontal dimension between the wall head and the joint of the top and bottom chords to approximately 1000mm.

Raised tie trusses are subject to horizontal deflection at their supports. Standard design practice is to limit this deflection at each end. As such it is important that the supporting structure is capable of accommodating this.

Activity

Define the horizontal deflection limit at supports at each end for raised tie trusses?

12.7 Bracing

Where trussed rafter roofs are concerned, it is important that they are correctly and adequately braced to ensure that the roof structure is rigid and stable. Bracing typically comprises longitudinal and diagonal members spanning across the trusses at specified locations and is typically provided using carcassing timber, fixed using nails.

Permanent roof bracing must be provided such that:

- the trusses remain upright, straight and at the correct centres
- they do not buckle or rotate out of plane when loaded
- the roof is able to stabilise the gable walls.

Temporary bracing may also be fixed to restrain the trusses during installation.

Bracing may be provided by wood-based panels or sarking boards fixed to the top of the rafters.

It is the responsibility of the building designer, rather than the truss designer, to provide the specification for roof bracing.

Activity

Explain why roof bracing is necessary and describe where and how it would be fixed to a trussed roof structure

Activity

Sketch a common duopitch trussed roof and show a typical bracing configuration, incorporating longitudinal and diagonal bracing members. Detail fixing locations, fixing type and number, and show the location of any laps where appropriate

12.8 Hip ends

Hip ends may be readily formed using trussed rafters. The framing principles used may be extended to produce more complicated roofscapes. Trussed rafters are designed using sophisticated computer software by specialist licensed manufacturers enabling most roof types to be feasible.

12.9 Spandrel panels

A spandrel panel is a structural timber frame panel fabricated to match the profile of the roof in order to form a party or gable wall. Spandrel panels are installed parallel to the roof trusses/rafters.

Spandrel panels are constructed in a similar manner to wall panels and typically comprise a structural frame, structural sheathing and membranes as appropriate. A spandrel panel may also be referred to as a gable panel.

Activity

Sketch a typical spandrel panel and label each of the components

Attic trusses being erected on site.

Roof truss detail.

Modular roof system.

OSB roof sheeting detail.

12.10 Gable ladders

A gable ladder provides a structural connection between roof trusses and spandrel panels. Gable ladders typically protrude beyond the spandrel panel to create eaves and are often used to provide a fixing for soffits and fascias.

Gable ladders comprise a simple timber frame of parallel members which span the roof structure and are connected at regular centres with shorter members such that the finished element resembles a ladder.

12.11 Roof cassettes

Roof cassettes are an alternative means to installing the roof traditionally - that is installing each roof component individually on site. Roof cassettes can be used as an alternative to attic trusses to provide an unobstructed roof space for occupation.
Roof cassettes are similar in construction to floor and wall cassettes and are manufactured offsite and installed onsite. Roof cassettes generally comprise a frame structure (typically rafters, structural sheathing and timber frame connectors) and may have insulation, membranes and internal linings installed in the factory prior to delivery.

It is common practice within the timber frame industry to include engineered timber products such as I-joists or open web joists into the structure as they lend themselves well to this application and by utilising engineered timber products into cassettes structural performance can be enhanced with the potential for large spans.

Internal elements are placed according to design specification on framing table, connected and braced using mechanical fasteners. Sheathing is then placed onto surface to create a cassette. Cassettes might also incorporate openings for windows and suchlike.

Roof cassettes are typically lifted into place using appropriate lifting apparatus connected to the supporting structure.

A growing number of unique modular roofing systems which utilise roof cassettes, typically in conjunction with spandrel panels, purlins, intermediate trusses and/or rafters are available.

12.12 Modular roofs

There are a number of modular roof systems currently on the market in the UK, utilising a variety of different methods and materials to produce entire roofs or sections of roofs offsite. Modular roofs are three dimensional units or modules, produced in factories using offsite methods under controlled conditions.

Modular roofs may be of cold or warm roof construction and the roof structure may, for example, be formed using trusses, I-joist or open web joist rafters, Glulam or LVL purlins, among others.

Modular roofs may be constructed using attic trusses, panels or SIPS to create an unobstructed roof space to provide additional living space.

Modular roofs may incorporate elements fitted during manufacture such as insulation, roof tiles, windows/skylights, fascias, soffit, guttering, dormers, PV units, internal linings, floors and suchlike. The configuration, materials, features and level of finish of modular roofing systems will vary between manufacturers, purpose, requirements and design.

It is common practice within the timber frame industry is to include engineered timber products such as I-joists or open web joists.

Modular roofs are typically delivered to site by lorry, either whole or in sections, then assembled on site. Modules are made watertight to ensure that their internal structure and finish are unaffected during transport and installation. The existing structure is designed specifically to receive the roof modules when they arrive on site.

Fixing positions for lifting are appropriately designed, lifting methods devised and the lifting process directed and undertaken by appropriately trained personnel to ensure that modules are lifted onto the existing structure safely and in such a manner to ensure that the existing structure, roof structure and finishes don't sustain any damage.

Some of the main benefits of a modular roofing system are:

- offsite manufacturing under factory controlled conditions, ensuring quality control, accuracy and consistency
- reduced time on site
- reduced delays due to adverse weather conditions
- reduced scaffold costs
- reduced on site storage requirement
- reduced requirement for on site trades
- minimised operations at height.

Activity

Which elements roof cassettes usually comprise?

Activity

Find out about a roof modular system that is currently on the market in the UK and give a short description of the general configuration, how it is formed and the materials used

13. Wall construction

13.1 Overview

Walls for timber frame construction are most typically constructed using individual rails, studs and sheathing, using various materials, to form ‘open’ or ‘closed’ panels which are manufactured in the factory and installed on site. Alternatively, walls may be SIPs or solid timber panels such as CLT, DLT or NLT.

Walls enclose and divide areas of common or separate occupation and support upper floors, walls and the roof structure.

Design considerations to meet fire, thermal and acoustic requirements are described in more detail in other sections of this workbook.

13.2 Load-bearing walls

Load-bearing walls must be designed and constructed in such a manner that they effectively and safely support and transfer loads to the foundations without undue movement. Upper storey, floor, roof and wind loads must be taken into consideration.

Lintels and cripple (multiple) studs should be provided at openings unless the opening doesn’t affect the centre spacing of the studs or loads are supported upon a perimeter support e.g. a rim beam.

Unless otherwise specified multiple studs or materials of increased dimensions and/or load carrying capacity should be included at locations where multiple joists are to be supported. Where head binders are not provided joists, trusses and similar loads should bear directly over studs or column members.

13.3 Non-load-bearing walls

Load-bearing and non-load-bearing internal walls are typically of similar construction to one another though the elements of a load bearing wall must provide enhanced load carrying capacity. This may be achieved through use of larger elements, stronger/stiffer elements, reducing centre to centre distances of elements, enhanced fixing details or fixing elements together to create multi-ply elements, among others. Non-load-bearing walls separate areas of a building and neither carry nor transfer loads.

13.4 Internal partitions

An internal wall, or internal partition, is a wall which separates two or more areas of a building of the same occupation. Internal walls may be load-bearing or non-load-bearing.

Typically, an internal wall in a timber frame dwelling will be of single leaf construction and comprise timber studs sheathed and/or lined on both faces with a suitable insulation material between the stud bays.

13.5 Party walls

Party walls, or separating walls, separate dwellings or areas of different purpose groups or occupation from one another. Party walls may also be used to divide buildings with large floor areas into smaller compartments to provide greater safety in the event of fire.

Party walls must provide a continuous vertical barrier to fire for the full height of the building including the roof space.

Party walls typically comprise two independent frames with a cavity between them. The frames are typically disconnected unless party wall straps are specified to provide restraint. This is the typical detail to obtain resistance to the passage of sound.

Party walls and junctions must be designed and constructed such that they resist the spread of fire between the buildings which share a common wall. Examples of types of buildings with party walls are semi-detached houses, terraced houses, or flats.

Service penetrations in party walls should be avoided or kept to a minimum for a number of reasons. If providing service boxes in the party wall is unavoidable they must not be fixed back to back and the rear of the service boxes must be protected by the same plasterboard used to line the party wall or a material of equivalent performance.

Activity

Which aspects should be considered when designing a load-bearing wall?

Junctions between party walls and separating floors, external walls and roofs must be designed and constructed in such a manner that the continuity of the building fabric is maintained to prevent energy loss, reduce flanking sound transmission and minimise spread of fire.

13.6 External walls

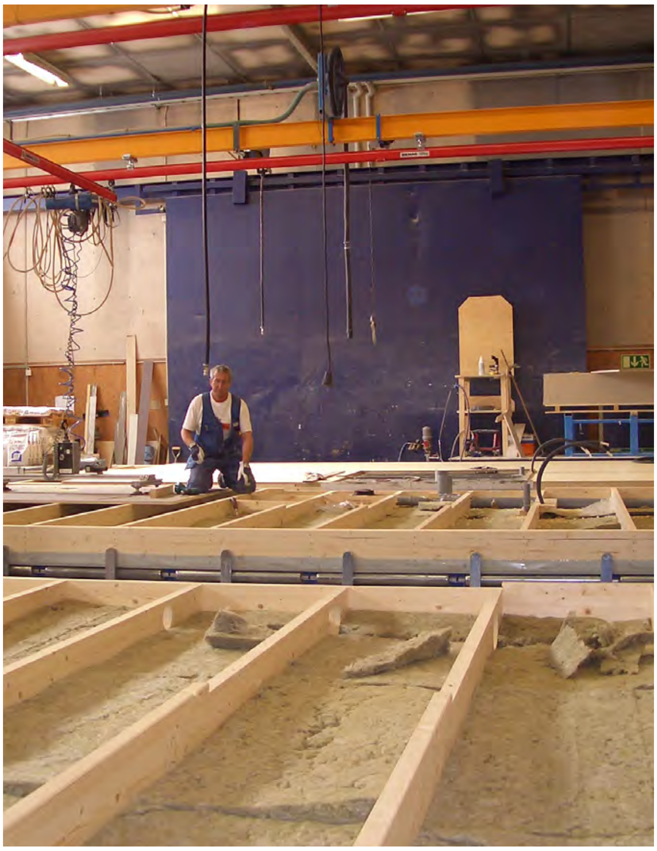
At their core, external timber frame walls are essentially of similar construction to internal timber frame walls, comprising at least a structural timber frame, structural sheathing material, insulating material and appropriate membranes.

External wall panels typically form the internal leaf of the external wall and are load-bearing, that is they carry and transfer load.

External walls typically comprise timber frame panels (internal leaf) and an external skin or leaf, most commonly masonry such as brick or block (external leaf).

Activity

List some reasons why it is recommended that service penetrations in party walls is avoided



Floor cassettes assembly.

Wall panel asembly line.

Added value activities.

Panel storage.

The timber frame panel (internal leaf) and external leaf are typically separated with a cavity and the external leaf fixed to the internal leaf using wall ties at regular vertical and horizontal centres.

Depending on the type of construction the external leaf may be supported independently by the foundations or attached to and supported by the timber frame.

External timber frame wall panels are capable of providing better thermal performance than traditional masonry walls of comparable thickness.

Timber frame panels may also be used as an external leaf. Careful design consideration must be given to many aspects, including fire resistance.

Where this is the case an external render or cladding system is typically applied to the external face of the panel to provide durability, withstand weathering and provide the desired architectural appearance.

13.7 Openings in walls

Openings in load-bearing timber frame wall panels for windows and doors should be framed out using strengthening, multiple stud members, or cripple studs, at either side and underneath the opening as appropriate. A lintel must be included directly underneath the top rail of the panel, at the head of the opening to ensure that loads are adequately transmitted to the cripple studs.

The number of cripple studs to be used will depend upon the size of the opening and the load that is being carried by the lintel.

It is not necessary to include a lintel where no vertical loads are applied to the head of the panel above an opening.

For most domestic applications timber lintels are adequate.

Lintel design will be determined by:

- the imposed load (uniformly distributed and point loads)
- the span of the opening
- availability of material
- deflection limits.

Activity

Sketch a timber frame wall panel with openings for a door and window, showing the top and bottom rails, studs, lintels and cripple studs

13.8 Support for point loads

Point loads from beams such as trimmers supported by the wall must be transmitted to the foundations. This can be achieved by using additional multi-ply studs at positions under such loads to provide a continuous load path.

Where specified, transfer of point loads must be continuous through all walls and floors to the foundations.

13.9 Open panel

Single sheathed panels comprise a structural frame, typically studs at regular centres affixed to top and bottom rails, typically of the same material and section size, sheathed on one side with a structural sheathing board and a breather membrane applied as appropriate, although the breather membrane may be fitted on-site. Insulation, internal linings, windows, doors, services, other membranes etc. are typically fitted on site once the open panels have been installed.

Panels may be either load-bearing (structural) or non-load-bearing (separating walls and partitions).

The panels are made 'open' on one side to receive insulation and services on site and are 'closed' by the internal lining material.

This system has a proven track record in the UK market and accounts for approximately 80% of timber frame used in the UK.

Open panels are easily fixed to the sole plate using nails or screws directly through the bottom rail before insulation and internal linings are installed.

Typically, a standard timber frame open panel comprises the following components:

- timber top and bottom rails
- timber studs at regular centres
- sheathing boards
- breather membrane

Once installed on site, timber head binders are fixed to the top of the wall panels to tie them together and spread uniformly distributed and point loads imposed by the upper floors, walls and roof structure.

13.10 Pre-insulated (may be closed) panel

Pre-insulated panel construction involves the creation of a structural element ready for installation offsite before being delivered to site. Pre-insulated panels consist of a structural frame (top and bottom rails connected by studs, usually at 400-600 mm centres). The structural frame may consist of solid timber, engineered timber systems or similar. The panel is then fitted with sheathing, membranes and insulation as per design.

For pre-insulated panels the insulation material is installed into the panel in the factory and this is then retained with some other layer of material to close the panel. As well as installing insulating material prior to closing the panel it may also be blown in once sheathing has been installed on both faces of the panel.

The frame structure is created with studs at prescribed spacings. Openings and reinforcing elements are inserted as per the design requirements.

Sheathing boards are then secured in place using mechanical fasteners at prescribed spacing.

Pre-insulated panels may have

services, windows, doors, finishes and cladding installed in the factory.

Closed panel systems generally allow more value to be added in the factory but often require service runs to be pre-planned. As they are also heavier than open panels, pre-insulated panels tend to require handling in the factory and erection on site by mechanical means.

Pre-insulated panels are used to create wall structures within timber structures. The timber frame transfers loads applied from any structural elements above to either a floor system or the structures foundations. The sheathing provides lateral or racking strength to the wall system.

Closed panel systems are used predominantly in domestic dwellings, however they can be used in low to medium rise buildings.

Panels should be loaded appropriately using lifting equipment and stacked either vertically or horizontally. They should also be wrapped with plastic to prevent water ingress during transport.

Installation should be carried out as soon as panels are delivered, storage on site should be undertaken in accordance with manufacturers guidance. Panels are typically connected via a soleplate to a load-bearing sub structure.

Innovative fixing details to soleplates are required as there is no access to top of the bottom rail due to sheathing being affixed to both faces of the panel.

Activity

List some of the benefits which pre-insulated panels offer over open panels

13.11 Solid timber wall panels

Solid timber panels, such as cross laminated timber (CLT), nail laminated timber (NLT) and dowel laminated timber (DLT) may be used as walls in a similar manner as standard timber frame panels for speed of installation and reduction of labour on site, though the design and detailing will differ and be dependent on the system and manufacturer.

Activity

List some of the benefits of using solid timber panels for walls

13.12 Breather membrane

A breather membrane repels water but is permeable to escaping water vapour. One of the key aspects for ensuring good long-term durability of the structure involves keeping the timber frame dry by providing a drained and vented cavity between the timber and outer cladding.

Reflective breather membranes improve the thermal performance of timber frame walls. The reflective coating reflects heat during warm months and reduces heat loss by inefficiently emitting heat in colder months.

The breather membrane should be installed on the cavity side of the structure.

13.13 Vapour control

In order to reduce the amount of water vapour entering the structure which would then condense as a result of the temperature differential then the internal face of the frame needs to have a greater resistance to water vapour than the external face of the frame. This is achieved by providing a vapour control layer (VCL) on the internal faces, typically behind the linings, on the warm side of the last layer of insulation. Although the VCL may be polythene (or similar) sheathing affixed to the frame it may also be incorporated in the lining e.g. vapour check plasterboard which has a VCL laminated on one face.

Solid (also termed massive) timber such as Cross Laminated Timber (CLT) may be used as walls to increase the speed of installation.

14. Floor construction

14.1 Overview

Timber floors may be constructed using individual joists which are pre-cut by the manufacturer or cut on site, then laid out, installed, insulated, and decked on site. Alternatively, the floor can be manufactured offsite as cassettes or solid timber panels such as CLT, DLT or NLT for speed of installation and reduction of labour on site.

Design considerations to meet fire, thermal and acoustic requirements are described in more detail in other sections of this workbook.

More detailed information on materials and floor components e.g. joists and connectors, is given in more detail in other sections of this workbook.

14.2 Ground floors

14.2.1 Concrete ground floors

Suspended timber, suspended concrete and in-site concrete floors supported on the ground can all be used for timber frame construction.

Ground floors must prevent moisture reaching the upper surface of the floor, minimise energy loss and prevent thermal bridging to the ground or into the ventilated space beneath suspended floors. As such, it is necessary to include damp proof membranes for suspended floors and ground-supported floors.

Typically, concrete ground floors for timber frame construction are similar to those used for other types of construction.

It is important to ensure that the ground floor is level and that support to the structure is uniform throughout to prevent differential settlement.

Activity

Sketch cross sections of some of the different types of suspended and ground supported concrete ground floors used for timber frame construction and label the components (use separate A4 page)

14.2.2 Timber suspended ground floors

A timber ground floor is normally provided by the supplier of the other timber components and is constructed sequentially with the timber frame superstructure.

Timber suspended ground floors may be supplied as pre-cut joists and associated components, as floor cassettes, or may even be cut to the correct lengths on site, although this is less common.

Similar to an intermediate floor, a timber suspended ground floor may be designed as a platform.

Timber suspended ground floors are particularly suitable for timber frame construction as they are typically manufactured and installed by the same trades as the rest of the kit.

It is vital that the ground beneath the timber suspended ground floor is covered with a suitable membrane to prevent the passage of moisture from the ground to the timber, and the growth of vegetation. The void beneath timber suspended ground floors must also be adequately ventilated.

It is important to ensure that the ground floor is level and that support to the structure is uniform throughout to prevent differential settlement.

Activity

What is necessary to consider when designing and installing a timber suspended ground floor?

14.3 Intermediate floors

Intermediate floors are those contained within a single occupancy to divide them into compartments.

Whether they are installed on site using pre-cut members or cassette, intermediate floors typically comprise a ceiling lining such as plasterboard, installed on the underside of the floor joists, typically solid timber, I-joists or open web joists, with a sub-deck such as OSB, plywood, or particle board, fitted to the top of the joists with a floor finish applied to the top of the sub-deck. Insulation may be fitted between the joists and between the sub-deck and floor finish if appropriate. Intermediate floors may also be manufactured using solid timber panels such as CLT, DLT or NLT.

Typically, a standard timber joisted intermediate floor comprises the following components:

- header joists or rim beams (forming the perimeter of the floor)
- floor joists
- trimmer
- trimming joists (supported on a trimmer)
- multi-ply members (other than trimmers)
- strutting or bracing
- connectors
- restraint straps
- partition noggings
- perimeter noggings
- floor deck
- insulation
- ceiling finish.

Activity

Sketch a cross section of an intermediate floor in common use by your company and label the components.

14.4 Separating floors

Separating, or party, floors are those that separate different occupancies or purpose groups or which divide a large building into a number of smaller compartments.

Separating floors are typically of similar construction to intermediate floors and typically comprise a ceiling lining such as plasterboard, installed on the underside of the floor joists, typically solid timber, I-joists or open web joists, with insulation fitted between the joists, a sub-deck such as OSB, plywood, or particle board, fitted to the top of the joists with a floor finish applied to the top of the sub-deck. Insulation may also be fitted between the sub-deck and floor finish if appropriate. Intermediate floors may also be manufactured using solid timber panels such as CLT, DLT or NLT.

Activity

Sketch a cross section of a separating floor constructed using solid timber panels and label the components

Activity

Explain the difference between an intermediate floor and a separating (party) floor

14.5 Floor cassettes

Floor cassettes are similar in configuration to closed panel timber frame elements. Cassettes generally comprise a frame structure, insulation, connectors and sheathing.

Common practice within the timber frame industry is to include engineered timber products such as I-joists or open web joists into the structure.

The cassette is manufactured offsite and installed onsite, reducing site costs and time as well as increasing product quality.

A significant advantage of floor cassettes is that once landed and secured they provide a safe working platform, enhancing speed and health and safety on site.

Internal elements are placed according to design specification on framing table, connected and braced using mechanical fasteners. Sheathing is then placed onto surface to create a cassette.

Cassettes should be loaded onto a flat-bed for transportation. Care must be taken to lift cassettes appropriately to ensure panels are not damaged due to poor lifting arrangement or reversal of forces.

Cassettes should be stacked horizontally and wrapped before transportation to prevent water ingress. If insulation and/or ceiling linings are installed in the factory then it is vital that these are protected from the elements during transport and erection, until the building is made watertight.

Cassettes are typically lifted into place using appropriate lifting apparatus and connected to the supporting structure.

Installation and site storage should be undertaken in accordance with the manufacturer's specification.

Floor and wall cassettes can be used in a variety of applications from domestic dwellings to large scale industrial units.

By utilising engineered timber products into cassettes structural performance can be enhanced with the potential for large spans.

Activity

List some of the benefits of using floor cassettes

14.6 Floor decking

The intermediate floor deck of a timber frame structure acts as a horizontal diaphragm which transmits lateral loads through to the walls. It is therefore vital that these are accurate and securely fastened.

Floor decks used for timber frame construction are most typically OSB, plywood, or particleboard.

The floor cassette is manufactured offsite and installed onsite, reducing site costs and time as well as increasing product quality.

15. Cladding

15.1 Overview

Cladding is a typically non-structural external skin/façade or coating. Although it can play a structural role by contributing to the transfer of wind and impact loads the primary function of cladding is to provide durability, weather resistance and architectural character.

Some other functions served by cladding are:

- contribution to the control of the internal environment
- reducing sound transmission
- providing thermal insulation
- contribution to the reduction in spread of fire
- providing an air tight envelope.

Cladding can generally be separated into two broad categories:

- self-supported cladding: supported on the foundations and tied back to the structure
- fully supported cladding: fixed to and fully supported by the timber frame structure.

Some examples of external cladding types are:

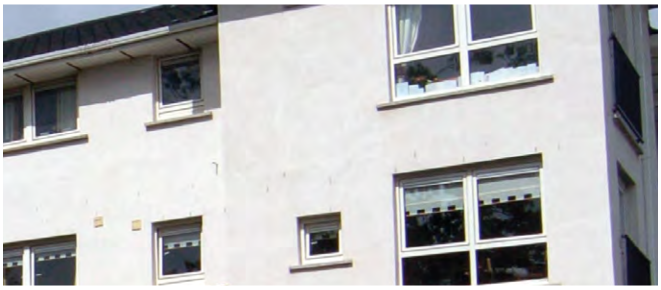
- brick
- block with a cement render
- tiles
- slates
- timber boards
- render on battens
- timber or metal panel or system specific render systems with integrated insulation.

Further reading:

Davies, I. & Wood, J., (2010). Exterior timber cladding: design, installation and performance.

Edinburgh: Arcamedia, ISBN 978-1-904320-04-3

Timber boards cladding.



Render cladding.

Brickwork cladding

16. Fire resistance

16.1 Overview

In order to minimise the risk of potential loss of life and property buildings must provide a degree of fire resistance and fire protection in accordance with the Building Regulations and corresponding documents.

Fire resistance is a measure of an element's ability to resist the effects of fire - potential collapse, penetration and/or transfer of heat - should a fire occur.

Fire resistance in a finished timber frame building is provided by internal linings, the timber structure itself and insulation materials.

Activity

Explain some of the means by which fire resistance is achieved in timber frame construction

The installation, position and materials used for cavity barriers should be in accordance with the relevant design requirements and regulations.

Guidance on how to meet the relevant requirements for each of the regions in the UK are given in the following publications and associated documents referenced within:

- England and Wales: Approved Document B (Fire Safety)
- Scotland: Technical Handbook Section 2 (Fire)
- Northern Ireland: Technical Booklet Part E (Fire Safety)

These should be read in conjunction with the relevant associated documents. It is essential to have an understanding of the requirements for fire performance in timber frame construction.

16.2 General

16.2.1 Use of plasterboard

In general, 1 layer of standard 12.5mm thick plasterboard provides 30 minutes of fire resistance. 60 minutes of fire resistance can be achieved by providing 2 layers of standard 12.5mm thick plasterboard.

Plasterboard which offers enhanced fire protection and increased periods of fire resistance when using a single layer is offered by a number of manufacturers and is readily available.

16.2.2 Fixing of plasterboard

In order to achieve adequate fire protection and reduce fire spread good workmanship and accuracy are essential when installing plasterboard. It is critical that plasterboard is installed correctly with edges fully supported, joints and junctions taped and filled and gaps adequately filled and sealed.

Plasterboard tape of two types can be used: paper and rim. These are applied at the joints of plasterboard, and then layers of jointing compound are added to create a single smooth surface. It is important to ensure that no gaps are left in this process.

If two layers of plasterboard are used joints should be staggered. Fixings must be of the correct specification, installed correctly and centre, edge and end distances adhered to. Any boards that have sustained damage should be replaced.

16.2.3 Products with enhanced fire resistance

There are varieties of non-combustible and limited combustibility products on the market which have been specifically designed and developed to provide enhanced fire resistance with increased periods of fire resistance.

Example products include:

- plasterboard with additives in the gypsum core
- solid timber and EWP joists with fire retardant (FR) treatment
- wood-based sheathing boards with FR treatment
- cement particle and magnesium oxide sheathing boards.

When specified, the fire performance of such products must be verified by the manufacturer.

16.2.4 Duration of fire resistance

The requirements for minimum durations of fire resistance vary depending on the building's purpose group and are given in the Building Regulations:

- England and Wales: requirements are dependent on height and occupancy
- Scotland: requirements are dependent on height, occupancy and compartment floor area
- Northern Ireland: requirements are dependent on height and occupancy.

Again, these should be read in conjunction with the relevant associated documents and not in isolation.

Activity

Find out the fire resistance duration requirements for the party walls and separating floors for a project in which you are currently involved

16.2.5 Compartmentation

The spread of fire within a building can be restricted by dividing it into separate compartments with walls and/or floors which have been designed and constructed to provide fire resistance.

It is essential that compartmentation is taken into consideration and that fire protection is correctly specified and installed in order to restrict and reduce the spread of fire both internally and externally.

16.2.6 Cavities and concealed spaces

In the event of a fire cavities and concealed spaces without cavity barriers in areas such as walls, floors, ceilings and roofs will allow flames and smoke to readily spread throughout the building, therefore cavity barriers must be provided in these locations as necessary. Cavity barriers essentially close the paths through which fire and smoke could travel should a fire occur.

Cavity barriers must be installed around the edges of the cavity and around openings and penetrations to restrict the spread of fire and smoke within the cavity. It may also be necessary to further sub-divide the cavity.

Cavity barriers should also be provided at junctions between elements and within voids such that the continuity of the fire resistance of those elements is maintained.

Cavity barriers must be installed such that they are adequately secured, bridge the full width of the cavity have no gaps. Cavity barriers should be lapped at joints and corners to ensure continuity is maintained.

16.3 Walls and partitions

16.3.1 Internal walls

Internal walls should be designed and constructed such that they are capable of withstanding the effects of fire without loss of stability for an appropriate duration.

Junctions with party walls, external walls, floors and ceilings should be designed such that they provide an adequate level of fire resistance and ensure that the continuity of fire resistance is maintained.

16.3.2 Party walls

Party walls must provide a continuous vertical barrier to fire for the full height of the building including the roof space.

Enhanced fire resistance is typically provided by using double layers of plasterboard with staggered joints.

Party walls and junctions must be designed and constructed such that they resist the spread of fire between the buildings which share a common wall. Examples of types of buildings with party walls are semi-detached houses, terraced houses, or flats.

Junctions between party walls and separating floors, external walls and roofs must be designed and constructed in such a manner that the continuity and duration of the fire resistance is maintained and such that fire in one part of the building is restricted from flanking the party wall or separating floor into another part of the building which is under different occupation.

16.3.3 External walls

To reduce the danger to occupants of neighbouring buildings the design and construction of external walls must be such that they provide adequate fire resistance to prevent the spread of fire across a relevant or notional boundary. The required fire resistance of external walls is dependent upon the building's use, height, size and its proximity to other buildings. The fire resistance of load-bearing walls must equal that of the floors which they support.

16.3.4 Openings in walls

The fire resistance of walls must not be compromised by any openings within them. Doors and windows must afford the same level of fire resistance as the wall into which they are fitted and the spread of flame via service panels must be restricted by suitable fire-stopping measures. The correct specification and installation of doors, windows and fire-stopping measures in openings is critical.

16.4 Floors

Intermediate and separating floors must provide a degree of fire resistance from the area beneath. Typically fire resistance is achieved by a combination of the ceiling lining, floor joists, insulation and sub-deck.

If the floor contains an access hatch it must when closed provide

the same fire resistance to that of the floor in to which it is installed.

Note there are no requirements for fire resistance for ground floors without a basement.

The walls upon which the separating floor is supported must provide the same fire resistance as the separating floor.

Joints between plasterboard layers must be staggered and the joints in the outer plasterboard lining must be taped and filled.

Although ceiling linings are typically plasterboard other lining materials may be used providing they provide adequate fire resistance. In all cases the manufacturer's instructions should be followed to ensure correct installation.

16.5 Roofs

Roof structures are typically constructed with trusses though the roof structure may comprise roof cassettes, SIPs panels or similar. However the roof is constructed effective compartmentation between dwellings must continue into the roof space and any junctions with the roof must maintain the continuity of fire resistance to provide resistance to the spread of flame.

Roof coverings must provide adequate protection to the spread of fire over them.

17. Acoustics

17.1 Overview

Sound insulation between and within dwellings must be provided. Separating walls and floors which divide attached dwellings (flats, maisonettes, terraced and semi-detached dwellings) must be designed and manufactured and installed correctly to provide adequate resistance to airborne, impact and flanking sound transmission.

Guidance on how to meet the relevant requirements for each of the regions in the UK is given in the following publications and associated documents referenced within:

- England and Wales: Approved Document E (Resistance to the passage of sound)
- Scotland: Technical Handbook Section 5 (Noise)
- Northern Ireland: Technical Booklet Part G (Resistance to the passage of sound).

These should be read in conjunction with the relevant associated documents. It is essential to have an understanding of the requirements for acoustic performance in timber frame construction.

17.2 Sound transmission

17.2.1 Airborne transmission

This is the level of sound insulation provided by the separating wall or floor for attached houses and apartments. This is measured in decibels (dB) in the completed building and compared to the relevant criteria such as $D_{nT,w} + C_{tr}$ for England and Wales and $D_{nT,w}$ for Scotland and Northern Ireland. The higher the value the better the insulation to protect against neighbour noise such as television, voices, music etc.

17.2.2 Impact transmission

This is the level of sound transmission through a separating floor for apartments. This is measured in decibels (dB) in the completed building and uses the $L'_{nT,w}$ criteria across the UK. The lower the value the less sound is transmitted from footfall noise etc.

17.2.3 Flanking transmission

Flanking sound transmission affects both airborne and impact sound insulation, and is the term used to describe a sound transmission path (structural or airborne) that is not directly through a separating wall or floor. Commonly the external wall can provide such pathways. Interpretation of laboratory sound insulation test results must account for flanking sound transmission.

17.3 Pre-completion testing

This is the testing mechanism adopted in completed buildings and requires a schedule of testing to be undertaken within the attached dwellings. An increased quantity

Activity

Which elements of construction in a typical three storey flat with a pitched roof normally require specific acoustic performance?

of testing would be required if there are changes in the design, specification and construction build-up of the separating walls or floors across a development.

17.4 Robust standard details

The Robust Details Scheme offers an alternative to pre-completion testing for new build adjoining dwellings i.e. dwellings which share a separating floor and/or party wall, for satisfying Part E of the Building Regulations (England & Wales).

The Robust Details Scheme can be used in Scotland as an alternative to pre-completion testing for new build dwellings to demonstrate compliance with Section 5.

The Robust Details Scheme can be used in Northern Ireland as an alternative to pre-completion testing for new build dwellings to demonstrate compliance with Part G.

A Robust Detail is a party wall or separating floor detail which has been assessed and approved by Robust Details Ltd. to consistently meet the requirements of the aforementioned regulations.

The Robust Details Handbook specifies (with photos) the approved Robust Details for party walls and separating floors of timber and masonry construction.

Buildings must be registered with Robust Details prior to commencing work on site.

This is a process whereby if the new build construction designs adopted are registered via robust details then pre-completion testing is not required. Site managers are required to complete check lists of the works and the site may be visited by a Robust Detail Inspector to check the works and undertake a sample test. Robust Detail separating walls and floors which appear in the RD Handbook have already been tested and approved, and are designed to have a mean performance better than the regulations, and thus do not require pre-completion testing. Approximately 70% of all new housing in England and Wales is registered with robust details.

The status of having a Robust Detail wall or floor system is recognised across the UK and simplifies the specification and approvals process.

17.5 Party walls

Refer to the Robust Standards Details Handbook for information of all standard details for party walls, including detailed drawings.

Enhanced resistance to sound transmission in a party wall is typically achieved by:

- increasing the mass of the wall sheathing i.e. by using a denser sheathing material e.g. plasterboard or adding additional layers
- increasing the overall width of the wall
- installing thicker and/or denser insulation within the wall
- reducing the connection between the wall leaves by increasing cavity depths or reducing the number and/or type of ties
- increasing the stud depth.

17.6 Separating floors

Refer to the Robust Standards Details Handbook for information of all standard details for separating floors, including detailed drawings.

Enhanced resistance to sound transmission in a separating floor is typically achieved by:

- increasing the mass of the walking surface and/or ceiling materials i.e. by using a denser sheathing material or adding additional layers
- increasing the overall depth of the separating floor
- installing thicker and/or denser insulation between the floor joists
- separating the sub-deck from the walking surface e.g. a floating floor on battens with a resilient layer
- reducing the connection between the joists and ceiling, most typically by installing resilient bars between the ceiling lining and the underside of the floor joists, though alternative systems e.g. metal frame ceiling or similar may be used
- adding insulation between floor battens
- installing flanking strips at the perimeter to separate the floating floor from the walls

- installing the appropriate number and type of noggings (noggins/dwangs).

17.7 Workmanship

Some potential workmanship issues to be aware of in party walls are as follows:

- stud depth
- distance between wall linings
- insulation correctly installed to ensure continuity and that no slump may occur during transportation
- incorrect installation of materials e.g. plasterboard and insulation types
- cavity width between leaves
- gaps & voids in plasterboard finishes
- staggered joints in wall linings
- sealed joints
- correct installation of services (service ducts, sockets, switches)
- connections between leaves
- fasteners.

Some potential workmanship issues to be aware of for in separating floors are as follows:

- correct installation of resilient bars on ceiling e.g. orientation of bars, removal of kinked/damaged sections, use of correct screw length for lining boards
- correct installation of ceiling system
- correct installation of ceiling lining – fasteners shouldn't touch or penetrate floor joists
- correct installation of insulation – no gaps or voids
- joints taped and filled (continuous)
- correct installation of floor battens e.g. batten layout, battens orientation, fixing lengths
- correct installation of flanking strips e.g. returned and folded under skirting boards
- correct installation of services e.g. stacked services should not 'fuse' floating floor systems.

Activity

How might you improve the acoustic performance of a party wall and separating floor?

18. Thermal insulation

18.1 Overview

The thermal performance of a building is considered an important factor in the way it operates and is constructed. The main objective of a buildings thermal performance is to be able to withstand the temperature and climatic fluctuations or hazards which it could encounter. The better the performance, the less energy is lost through its fabric which indicates that the building will need less energy to heat or cool its interior. This in turn will reduce energy bills, lay off pressure on fossil fuel depletion, and reduce the buildings carbon footprint thus becoming an environmentally sound building.

Thermal performance refers to how effectively a structure responds to changes in external temperatures during daily and seasonal cycles.

Thermal properties related to the envelope of a building are of great interest when assessing a building's performance. It’s important to take into consideration the way energy is contained or lost in a building and how this is achieved. To control this, buildings have an envelope which consists of its: floor, walls, roof, windows, and doors; and it controls the temperature differences between outdoor and indoor fluctuations.

The buildings envelope is derived from different building materials and components which possess different thermal properties controlling the amount and rate of energy leakage. Depending on its thermal properties and the way each component is placed the amount of heat loss can be calculated and regulated.

The correct selection of materials for the reduction of heat loss is best undertaken early in the design stage.

One of the ways to reduce temperature fluctuation and reduce heat loss is to insulate all components of a building as much as possible. To maintain constant temperatures in a building it is necessary to limit and reduce the rate at which heat can be conducted through a component. Insulation can work in two ways; either limiting solar gains to pass into a building, typically during summer months, or by keeping buildings heated and keeping heat that is produced inside the building, typically during winter months.

Note that insulation materials also contribute to the fire resistance and acoustic performance of the building element.

18.2 General requirements

Insulation should be installed throughout the building, most typically:

- **Walls:** in an un-insulated building around 35% of the heat loss is through the walls. This however is easily prevented and reduced with proper insulation. Different materials and methods may be used depending upon the wall structure
- **Roof/loft space:** in a poorly

insulated building approximately 25% of the heat loss is through the roof space. Heat generated indoors rises and conducts itself through the ceiling and meets a cold and sometimes humid void with a high volume of space. This in combination with materials in close contact with external conditions results in an easy escape route for generated heat

  - **Cold roof construction:** generally, the roof space is unventilated and sealed and insulation is situated in the ceiling zone
  - **Warm roof construction:** generally, the roof space is ventilated and sealed and insulation material is situated in the rafters

- **Floors:** for floors the percentage of heat loss is an average of approximately 15%. Insulation should be installed in the floor zone to prevent heat loss through the floor
- **Piping & storage tanks:** it's advisable to insulate all components which contain and transport usable water as much as possible especially those used for hot water. Cold water piping should be insulated to prevent them from freezing and becoming damaged. Water tanks should also to be insulated.

There are no thermal insulation requirements for intermediate floors other than a few exceptions:

- where a floor projects beyond the wall beneath
- where a floor is over an unheated space such as a garage
- where the floor forms an upper balcony
- where the floor abuts a roof space which is adjacent to an attic room.

18.3 Building regulations

Guidance on how to meet the relevant requirements for each of the regions in the UK are given in the following publications and associated documents referenced within:

- England and Wales: Approved Document L (Conservation of fuel and power)
- Scotland: Technical Handbook Section 6 (Energy)
- Northern Ireland: Technical Booklet Parts F1 & F2 (Conservation of fuel and power).

These should be read in conjunction with the relevant associated documents. It is essential to have an understanding of the requirements for thermal performance in timber frame construction.

18.4 Insulation material

Insulation materials can generally be divided into two types; man-made/synthetic and environmental/natural. Both have very similar effects but differ in the means by which they are obtained or produced.

The majority of manufactured or industrial insulating materials are man-made and mass produced in such a way that they can be widely and easily obtained. Some of these materials have a high embodied energy, that is they require a large amount of energy to produce, and therefore can counter effect the purpose of reducing carbon emissions of other building materials.

Environmental products are the opposite as they are obtained by greener means and may originate from vegetation, animal fur, recycled materials, and re-use or surplus of textiles for example. They tend to be more locally sourced and have low embodied energy i.e. they require little energy to produce, as they can be recycled and so are a by-product of another process or have previously fitted another purpose.

Some typical examples of insulating materials available for use in timber frame construction are:

- Man-made insulating materials
  - mineral wool
  - rock wool
  - fibreglass
  - rigid polyurethane (PUR)
  - rigid polyisocyanurate (PIR)
  - expanded polystyrene (EPS)
  - lightweight concrete
- Environmental insulating materials
  - wood fibre
  - cork/cork granules:
  - newspaper
  - sheep's wool
  - hemp
  - textile residue

18.5 Thermal conductivity

This is the measurement of a materials capacity to conduct heat. Thermal conductivity is widely regarded as the lambda (λ) or k-value and is the amount of heat flow in watts across a thickness of 1 metre of material for a temperature difference of 1° Kelvin in an area of 1 square metre. The unit of the coefficient of thermal conductivity is measured in W/mK and the greater the value, the more energy is conducted across the material at a quicker rate.

18.6 Thermal resistance

Building materials present resistance to the flow of heat. The resistivity is the inverse of conductivity, i.e. 1/λ and the resistance (R) of a material acts directly with the thickness of the material. The overall resistance of a building's components is not only the sum of the materials' resistances but also the resistance to heat flow of the external and internal surfaces and any cavities in the component. A surface resistance heat transfer acts according to the materials absorption, emissivity and reflectivity.

The surface resistances of materials in building components are measured in the same units as resistances of specific thicknesses of materials, therefore you can add up the resistances of each material making up components in a wall, roof, floor etc. to obtain a total resistance. As such the thermal transmittance of a building component can be obtained by using the sum of resistances.

18.7 Thermal transmittance (U-value)

All heat transfer modes are used when heat passes out of a building's envelope. The overall rate of transmission is known as the thermal transmittance.

Layers of different materials conduct heat at different rates. All of these factors can be measured and described by the thermal transmittance coefficient widely known as the U-value (W/m^2K). This coefficient measures the rate of heat flow in watts through 1 square metre of a structure when there is a temperature difference across the structure of 1° (C or K). These calculations are mainly

The U-value measures the rate of heat flow in watts through 1 square metre of a structure when there is a temperature difference across the structure of 1° (C or K).

aimed at building components based on various materials.

18.8 Factors affecting thermal performance and heat loss

Some factors which may affect a building's thermal performance and contribute to heat loss are as follows:

- insulation properties of the building envelope: a building that is well insulated limits heat loss
- exposure to the exterior: the greater the exposure the greater the heat loss – determined by type of building i.e. terraced, detached, semi-detached, flats etc.
- indoor and outdoor temperature differential: a large fluctuation between in and outdoor temperatures increases heat loss by convection.
- air change rate: warm air leaving the building is replaced with cold air. Air infiltration can happen through windows, doors (openings) and badly joined components
- external climate contact: wind blowing directly against a surface e.g. a wall or roof, it increases the heat transfer. This effect influences the surface U-value of materials
- efficiency of services and patterns of use: heat can be recycled for space heating and water heating.
- U-values of the individual components: e.g. wall, roof, openings/windows
- material specification: correctly specified products installed as per manufacturer's instructions
- workmanship: all elements must be correctly installed in accordance with the design, regulations and manufacturer's instruction
- air tightness
- thermal bridging
- natural light (solar gain)
- heating system
- artificial lighting
- ventilation.

18.9 Thermal bridging

Thermal bridging (may also be referred to as cold bridging) occurs when part of the building envelope is penetrated by a material/component with high thermal conductivity and at interfaces between elements of the structure where there is a gap or discontinuity in the insulation material.

Thermal bridging reduces energy efficiency and allows moisture in the form of condensation causing issues with thermal comfort, air quality and degradation of materials.

One cause of construction with low energy efficiency may be thermal bridging.

Thermal bridging typically occurs in walls, windows, doors, roofs and floors. It occurs when a material passes over insulation creating a cold bridge which causes heat to escape in corners, around windows, doors, and in any component. Cold bridges also appear where insulation is unable to make contact in areas such as between rafters, cornered walls where a cavity is discontinuous, or where a steel beam thermally conducts heat and bypasses insulation systems. This occurs as heat flows through the easiest path from a heated space to the outside – usually the path with the least resistance.

Thermal bridging can create other problems - when a surface temperature of an inner face of the wall falls below dew point temperature (condensation saturation point) humidity appears, producing mould. This can create larger U-values in materials and increase thermal conduction. This effect is enhanced where there is no ventilation.

To prevent thermal bridging a series of thermal breaks are incorporated at the design stage. An excellent example of this is in lintels across windows and door openings. Traditionally a single concrete member supported both leaves of cavity walls facilitating the passage of heat. Now a rigid insulating material is used under the traditional cavity insulating fill and thus reduces thermal bridging through cavity gaps. Other materials around window frames are used like cavity closers. Another way to prevent bridging is to combine aluminium frames of windows and doors with a lower thermally conductive material like timber which can internally wrap around the frame. In corners, it can be difficult to avoid bridging especially with perimeters of solid ground floors. Wall insulation usually can avoid this but it's where cavities meet in corners that heat loss can occur. Also, walls which do not meet adequately underneath the floor slabs can present thermal bridging. Linking rigid insulation in critical meeting points within the wall and the floor can solve most cases. In roofs this can also occur where wall insulation does not connect with loft insulation, creating a break in those corners.

18.10 Air tightness

The effects of wind hitting the external envelope of a building affects the rate at which it can lose heated air and enhance infiltration within various building components. Infiltration can happen when many materials are bonded with each other but have been placed poorly and small holes, cracks, or dents appear making the component "leaky" - in other words the building is not air tight. By ensuring a building is air tight, a reduction of heated air can be prevented from escaping. Usually this occurs at badly fitted windows and doors or between lintels or window sills.

The term "air-tightness" can be a controversial one in energy efficient construction methods as it is necessary to reduce infiltration but also important that buildings become self- breathable or ventilated to reduce condensation yet also increase buildings comfort by taking in fresh, breathable air for its occupants. Air tightness tests can be made to determine how much air is escaping from a building. Infrared equipment may also be used to pinpoint exactly where air is leaking.

The importance of careful consideration at the design stage, maintaining a high standard of construction and paying close attention to detailing while assembling components should not be underestimated – each individually or in combination may be as beneficial as physically increasing the amount of insulation. As small as a crack or hole can be, air has an easy way out and can eventually become the main problem in dampness and air leakage in a building.

Infiltration can be reduced by using insulated sealed doors and using insulated cavity closers around window sills to prevent thermal bridging. Other than that, a properly fitted window with sufficient sealant and careful cornering can reduce heat loss. Careful consideration should be made to older constructions with single layered walls as cracks and holes in corners are common and if ignored can increase infiltration.

In accordance with the Building Regulations it is a mandatory requirement that developers verify the air tightness of a sample of new buildings on any development. This can be achieved by air leakage testing.

Activity

How might you improve the thermal performance of a party wall and separating floor?

19. Vapour control and air barriers

19.1 Overview

Timber structures should be suitably protected from the effects of moisture and have a good level of air tightness. It is necessary to ensure that under normal conditions surface mould on walls and condensation are avoided and that air leakage is reduced. In timber frame walls, thermal insulation is typically packed between the studs, thereby maintaining internal surface temperatures above the dew point and preventing condensation.

Because timber frame buildings incorporate high levels of insulation within the structural elements and can achieve U-values significantly better than the minimum building requirements then water vapour must be adequately controlled.

By ensuring a building is air tight, a reduction of heated air can be prevented from escaping. It is important for the purposes of energy efficiency and thermal comfort of occupants for the building to have a good level of air tightness. As well as increased levels of insulation it is important to reduce air leakage, both warm air leaking out and cold air leaking in. Air leakage must also be reduced such that any benefits of energy efficient heating systems aren't negated.

19.2 General requirements and considerations

19.2.1 Warm side of a timber frame structure

The warm side of a timber frame structure is that beyond the internal side of the last layer of insulation.

19.2.2 Moisture content of timber frame

In general, solid timber is typically installed at around 16-18% moisture content, and not greater than 20%, but reduces down to around 10% in a heated building in service.

19.2.3 Considerations prior to installation

Surfaces should be dry and free from dust and debris. Ensure everything is correctly fitted and sealed before fitting any linings.

Membranes should be fitted from the lowest level up to prevent any moisture which may run down the wall from running behind them.

19.2.4 Window and door openings

Membranes should be lapped into openings, at the corners of openings and be adequately sealed as appropriate and in accordance with the manufacturer's instructions.

19.2.5 Party walls

Party walls should be treated as external walls and provide a continuous air barrier.

19.2.6 Internal walls

Where internal walls/partitions abut external walls they must not penetrate the air barrier. As such, internal walls should be installed once external walls have been completed.

19.2.7 Service penetrations

Membrane must be cut at locations where services e.g. pipes, ducts, cables, pass through. Where this is the case gaps around services penetrations and the membrane must be sealed using compatible tape or suitable proprietary sealing system as per manufacturer's instructions.

19.3 Vapour control layer

In order to reduce the amount of water vapour entering the structure which would then condense as a result of the temperature differential then the internal face of the frame needs to have a greater resistance to water vapour than the external face of the frame. This is achieved by providing a vapour control layer (VCL) on the internal faces, typically behind the linings, on the warm side of the last layer of insulation. Although the VCL may be polythene (or similar) sheathing affixed to the frame it may also be incorporated in the lining e.g. vapour check plasterboard which has a VCL laminated on one face.

Surfaces should be dry and free from dust or debris before the breather membrane is fitted.

The VCL should be securely fastened, lapped at joints and corners of openings and maintain continuity over the wall surface. To ensure the building envelope is air tight the VCL should be sealed at joints, junctions, corners and openings using a suitable tape or sealing strip compatible with the membrane and as per the manufacturer's instructions. Ripples or folds in the membrane must be avoided. If it is absolutely necessary to incorporate folds at any locations, it is important to ensure that the seal is adequate. Any service penetrations must be adequately sealed.

Cavities should be of a suitable width and adequately drained and ventilated to prevent the risk of external moisture penetration, prevent the build-up of moisture and allow a degree of movement of air.

Any damage to the VCL e.g. tears or punctures, should be repaired as the damage occurs, using the same material, adequately lapped around the existing material and securely fixed and sealed as appropriate.

19.4 Air barrier

Typically, the VCL also serves as a continuous air barrier and improves air tightness by reducing air leakage. In timber frame construction where the VCL is incorporated in the fabric of the building to control moisture it is also the most common means of providing the air barrier. In addition to reducing condensation, as described above, it is also important to provide a VCL to increase the air tightness of the building envelope for the purpose of improved energy efficiency and thermal comfort.

The most effective means of creating an air barrier in timber frame construction is with the VCL, as it can be sealed appropriately, gaskets can be readily provided around service penetrations and tears and/or punctures can be easily repaired.

Alternative means of providing an effective air barrier other than the VCL are:

- wet plaster internally ensuring all elements are covered at junctions, joints and corners
- sealed composite dry lining, sealed using tape or similar around all junctions, joints and corners between the sheathing material e.g. OSB, lining e.g. plasterboard, or other panel systems.

Whatever the means of providing an air barrier it should be installed at first fix and sealed at second fix. It is typically the responsibility of the insulation contractor or the post services contractor to install the air barrier.

19.5 Breather membrane

A breather membrane repels water but is permeable to escaping water vapour. One of the key aspects for ensuring good long-term durability of the structure involves keeping the timber frame dry by providing a drained and vented cavity between the timber and outer cladding.

Reflective breather membranes improve the thermal performance of timber frame walls. The reflective coating reflects heat during warm months and reduces heat loss by inefficiently emitting heat in colder months.

The breather membrane should be installed on the cavity side of the structure.

It is important that the breather membrane is installed correctly and accurately and that it incurs no damage during installation or once it has been installed.

Surfaces should be dry and free from dust or debris before the breather membrane is fitted.

The breather membrane must be of the correct specification and must be fixed and lapped in accordance with the manufacturer's instructions.

The breather membrane is most typically fixed at regular centres using staples. It is important to observe the staple type, fixing pattern and fixing centres to ensure that the breather membrane is installed correctly and in accordance with the specification.

The breather membrane should be securely fastened, lapped at joints and corners of openings and maintain continuity over the wall surface. Stainless steel staples are most commonly used. Ripples or folds in the breather membrane must be avoided.

PVC strips or similar should be positioned on top of the breather membrane at stud positions to reinforce the membrane and simplify the correct location of wall ties where appropriate i.e. the strips clearly identify the position of the studs.

Any damage to the breather membrane e.g. tears or punctures, should be repaired as the damage occurs, using the same material, adequately lapped around the existing material and securely stapled.

Activity

What is the main purpose of:

A vapour control layer

Breather membrane

An air barrier

Timber is typically installed at around 16-18% moisture content, and not greater than 20%, but reduces down to around 10% in a heated building in service.

20. Differential movement

20.1 Overview

As the timber frame dries it shrinks and the overall height reduces resulting in differential movement between the timber frame and other parts of the structure. The compression on the connections is also affected by differential movemnt. The timber frame elements may move differently to the cladding or other members adjacent to the timber frame elements. This difference between the movement of the cladding and the structure is termed differential movement.

The extent of differential movement becomes greater as the number of storeys increases.

The magnitude of differential movement increases as the structure increases in height - that is higher structures such as those of multi-storey construction will have a greater degree of differential movement as you travel up the structure. An accumulation of these dimensional changes results in the greatest movement being at the top of the structure.

It is important that differential movement is taken into consideration by designers and site personnel. As timber dries out, its cross-section shrinks and the structure settles.

Timber is stable in the longitudinal direction. However, some shrinkage is possible across the grain. This means an allowance has to be made in the floor zone where joists are lying 'across the grain'. The difference between the timber frame movement and the external brick is the differential movement.

20.2 Why it occurs

The main contributing factors to differential movement of the timber frame are:

- changes in moisture content of timber members
- compression of timber members under load
- closing up of joints and connections under load.

Because of the effects of moisture upon timber its dimensions change in relation to its moisture content. As timber dries its moisture content reduces and it shrinks. Conversely as timber becomes wetter its moisture content increase and so it swells.

Dimensional changes in timber do not occur equally in all directions. Generally dimensional changes in timber will be greatest tangentially/parallel to the growth rings and less so radially/perpendicular to the growth rings. The dimensional stability of timber in the longitudinal direction/along the grain is greater yet some shrinkage may still occur although it is likely to be minimal.

Solid timber is typically installed with a moisture content of around 16-18%, and no greater than 20%. Once enclosed the moisture content of the timber in a building will reduce and the timber shrink over a period of time.

The majority of movement in the frame generally occurs within the floor zone as the concentration of timber members which are oriented horizontally tends to be greatest in these areas i.e. wall panel top rail, head binder, joist, soleplate, wall panel bottom rail etc.

Cladding materials also change dimensionally over time but not in tandem with the timber elements.

Building elements will change dimensionally to a different degree and at different rates. Provision must be made to allow such dimensional changes to occur within the structure without sustaining damage.

As the structure is loaded joints and connections between members and elements will also close up to some extent and also contribute to differential movement.

It is generally good practice to 'pre-load' the timber frame structure prior to completion by installing the roof covering e.g. concrete tiles, internal linings and loading out floors prior to installation of external cladding provided that doing so is within structural limits.

20.3 Where it occurs

Differential movement typically occurs at the following locations in a building:

- floor zones
- openings – e.g. at sills, lintels, around windows (depending on construction)
- roof verges and eaves (masonry must stop short of soffit or rafters)
- masonry cladding – typically self-supporting
- non-masonry cladding e.g. steel sheathing, timber boards – differential movement between the cladding and the timber frame. May be fixed to the frame
- at locations where timber overhangs brickwork
- flues and chimneys, including

Activity

Calculate the differential movement at eaves and window sill levels for a particular project of greater than three storeys in which you are involved false chimneys

- overflow pipes and soil vent pipes
- balconies
- traditionally constructed stair cores
- lift shaft enclosures
- services e.g. soil vent pipes, cables etc. (services running vertically must take into account the shortening of the building).

The degree of settlement may be more apparent in some locations than in others and increases as the building. Adequate provision for movement must be provided as appropriate.

20.4 Implications of settlement

As elements which interface with one another change dimensionally at different rates and magnitude allowance must be made to allow movement at such joints. Direct abutment must be avoided to prevent damage from occurring as a result of differential movement

Any material or component attached to the timber frame structure which overhangs (e.g. cladding, sills, roof eaves) or projects through (soil vent pipe, balconies) the masonry must have an adequate gap which permits the occurrence of differential movement without causing damage to the structure or cladding.

Adequate gaps must be provided between such elements. Gaps must be filled using a compressible sealant or spacers to seal and create a flexible joint. The requirement and location for the provision of movement joints will be dependent upon the design and construction. Refer to drawing details, specification and manufacturer's instructions.

The differential movement between timber and masonry elements becomes greater higher up the structure and gaps become larger as a result.

That being the case provision must be made in upper storeys for this increased movement.

Use of high movement wall ties for levels above 3 storeys where differential movement is likely to exceed the capacity of standard wall ties.

To ensure weather tightness it may be necessary to provide flashings to certain elements and at certain locations. Check design, spec and drawings.

Any material or component attached to the timber frame structure which overhangs or projects through masonry cladding must have an adequate gap beneath it to allow differential movement to take place without damage to the structure or the cladding.

Gaps should be explained and their filling specified.

20.5 Reducing shrinkage

Vertical shrinkage can be reduced by:

- using engineered wood products e.g. I-joists, open web joists, LVL, Glulam or super-dry timber. These have a lower moisture content, will have been protected from the elements prior to installation and are more dimensionally stable than solid timber
- where solid timber sections are used in floors and walls try to limit the quantity of cross-grained timber that is used as much as is practicable
- ensuring that the design and construction make allowances for settlement
- ensuring that adequate gaps are left to take up the downward movement of the frame
- keeping timber materials as dry as possible
- good workmanship – tightly fitting joints etc.

20.6 Control measures

Control measures/precautions should be taken both on and offsite to reduce potential issues due to differential movement:

- ensuring timber materials are kept dry prior to and during construction wherever practicable and in accordance with manufacturer's guidelines
- design, specification and installation of high movement wall ties, gaps etc.
- leave adequate gaps and fill to create movement joints
- correct and accurate design and detailing
- workmanship
- ensure correct gap filling method and spec. Check compressibility of materials.

21. Engineering

21.1 Overview

By definition, timber frame construction is a method of construction whereby timber members and sheathing are combined to form a structural frame which effectively transmits horizontal and vertical loads (e.g. those applied by self-weight and wind) to the foundations. Therefore, understanding the load types and paths within timber frame buildings is crucial for safe structural design. The aim of structural design is to provide stability to the building. The following sections discuss the most common designs for vertical and horizontal loads.

The designer should be familiar with the 'dead' loadings that are generated by the building and the 'live loads' generated by its occupants and external forces. These travel through the building structure, down to the foundations from the roof, floors, and walls.

Loads are measured in force per area, most often kN/m^2.

21.2 Load paths

Since it is impossible to know exactly how any applied loads will be distributed through a building in practice, it is standard engineering practice to create an idealised, simplified model of the structure. The ways that the loads are distributed through this model are known as the load paths.

21.3 Vertical loads

21.3.1 Dead loads

Dead loads are the loads of the building itself, that is the structural timber frame, the roof, wall and floor structures, the cladding, windows, doors, roof tiles, etc. Firstly, the building must be structurally stable under the forces of gravity acting from the listed components. In general, the dead loads remain constant throughout the building's use.

21.3.2 Live loads

Live loads change throughout the building's useful life, as they reflect the fluctuating forces imposed by the building occupants, their furniture, etc. Live loads are calculated using established estimate loads per room and building type. For example, the live loads in a hotel building will be different from those in a school building or a house.

21.3.3 Roof loads

Roof loads are caused by the additional vertical forces acting on the roof during and after snowfall. The weight of snow accumulates on the roof structure and imposes additional live loads on the building. The structural design must accommodate for these loads to ensure the structural stability of the building in the case of high snowfall. The shape of the roof, the roof surface and the building surroundings all impact design for snow loads.

Snow loads are usually categorised as a short-term load duration class, as described in BS EN 1995-1-1, Table NA.1

21.4 Horizontal loads

21.4.1 Wind/racking

Horizontal wind forces on walls perpendicular to the wind direction have to be transferred to the ground via walls parallel, or near to parallel to the wind. The forces are taken to be transferred by the diaphragm action of the floors and the ceiling plane of the roof.

The rapid movement of air causes wind forces, which in turn cause areas with positive pressure on the wind-swept surface of the building and negative pressure on the opposite building surface. The direction of the wind, the wind velocity and the surrounding terrain affect the wind forces values and acting points.

Wind forces acting on the walls of the building are transferred via the floor diaphragm and roof diagonal bracing / ceiling diaphragm to the external and internal cross walls.

These walls carry this horizontal load down to ground level utilising their racking resistance. At each level sufficient fastenings are required to transmit the accumulating load to the floor below. The soleplate fixings transfer the horizontal wind load into the foundations.

A timber stud wall panel frame has no inherent resistance to horizontal forces such as wind, known as racking forces, which will push it out of square. In the UK it is normal practice to sheath external wall panels with materials such as OSB, plywood, cement particleboard, MgO etc. to provide racking resistance. It is also possible to provide racking resistance by other means than sheathing the panel, such as diagonal braces or specially designed trussed panels for example.

The structural engineer's marked up layout shows racking walls, special nailing specifications, and roof/floor wall connection requirements. These must all be accounted for in the timber frame designs and manufacturing information.

21.4.2 Uplift

In the case of extreme horizontal wind loads the roof of the building may be uplifted from the structure, therefore causing great damage and risk to people's lives. Uplift is most commonly caused by excessive pressure concentrated on the wall-to-roof edges of the building. Protrusions, such as roof overhangs can create high wind load areas in the case of wind forces acting with high velocity. It is paramount that the structural design is undertaken to prevent uplift of the roof structure.

The designer should actively seek the engineer's guidance on the specific methods on holding down required on each project.

Causes of wind uplift include:

- high wind speed areas
- exposed sites
- low roof pitches
- large overhangs
- lightweight roof claddings.

Truss clips are the normal method of restraining roof members but higher uplift forces may require special detailing. High level wall panels may need strapping to lower levels to ensure they are not lifted by the wind uplift forces.

21.5 Disproportionate collapse

The designer should be familiar with the effects of wind loads on the building and any special requirements to resist disproportionate collapse. Disproportionate collapse is a structural building failure, caused by an external force, in which the building is not proportionally damaged, that is some areas are more damaged than others. Ronan Point, Newham, London is the most commonly used example of progressive and disproportionate collapse in the UK.

Disproportionate collapse affects the building design and calculations to prevent it need to be incorporated into the timber

Activity

List all the vertical and horizontal loads acting upon the structure for a particular project in which you are involved

frame design package. To design for disproportionate collapse prevention, the building robustness in accidental events must be ensured in the structural design. This is achieved by calculations for accidental events, such as earthquakes or explosions, which may affect the specific building. These calculations are done individually for every building and are therefore termed case-specific.

Disproportionate collapse must be prevented by design in accordance with the Eurocodes, as part of the accidental design situations. Disproportionate collapse is a critical consideration for multi-storey buildings.

Methods by which progressive collapse may occur in a timber building are the following:

- loss of equilibrium of part, or all, of the structure
- failure by excessive deformation
- failure as a mechanism
- failure due to rupture
- failure due to loss of stability.

Methods for ensuring **robustness** of the building are the following:

- minimising hazards to which the structure can be exposed
- choosing a structural form that will be least affected by the types of hazards designed for
- selecting a structure that can survive localised damage including the removal of an individual member or a limited part of the structure
- avoiding as far as possible structural systems that can collapse without warning
- tying the structural members together.

21.6 Structural calculation principles

It is anticipated that the timber frame fabrication designer won't undertake engineering calculations, however the following background information will be useful to facilitate collaboration between the timber frame designer and timber frame engineer.

Timber frame buildings in the UK are usually designed in accordance with BS EN 1995 Eurocode 5: Design of timber structures and the UK National Annex Part 1.

Unlike other common structural materials, timber is capable of sustaining higher loads for short periods than it can over long periods. It is therefore necessary to check timber members for different load durations, depending upon the types of load applied. Note that due to its relative lack of stiffness when compared to strength, for many members deflection may be the limiting factor rather than strength.

Excluding floors and walls the design of a timber frame building may be separated into the following specific design processes:

Lintels: in addition to the strength of the lintel in bending, its shear capacity, deflection and bearing area of its supports require checks.

Studs: timber studs are subject to axial and lateral loading. The deflection of the stud under wind load needs to be considered. In addition, for all studs (including those supporting concentrated loads and lintels) the bearing capacity of the bottom rail of the panel onto which it bears must also be checked as this is often the limiting factor in the load capacity of a stud, particularly those not subject to wind load. Multiple studs or posts supporting concentrated loads, such as girder trusses or floor trimmers, and cripple studs supporting door or window lintels are designed in a similar manner to general studs.

Racking resistance of wall panels: racking resistance may be calculated in accordance with Eurocode 5. The factors which affect racking resistance are:

- type and thickness of sheathing material
- the diameter and spacing of the fasteners used to fix the sheathing to the frame
- presence of sheathing on one or both sides
- panel dimensions – height and length
- extent of openings in the wall
- permanent dead load applied to the head of the panels.

Overturning of the structure: the restoring moments have to exceed the overturning moments by a sufficient margin to provide a factor of safety. This is not likely to be a problem with typical low rise timber frame but may be for multi-storey with lightweight cladding.

Sliding resistance of the structure: sufficient anchorage must be provided to prevent the timber frame from being moved horizontally by wind pressure. Restraint is normally provided by securing the soleplate to the ground floor slab and nailing horizontal junctions, such as the bottom rail of panels to the floor decks. Alternatively, proprietary soleplate anchors or specials may be used as appropriate.

Uplift of the structure: wind passing over a pitched or flat roof can produce a suction force which will try to lift the building vertically. This is countered by the dead weight of the building. If there is insufficient dead weight to provide a sufficient factor of safety against uplift, ties will need to be provided to mobilise additional dead weight e.g. any masonry cladding or in extreme cases the foundations.

21.7 Loading information

All of the above structural information must be clearly identified in the timber frame design information packages produced for manufacturing, site erection, and structural checking.

Clearly identified information on general layout drawings can alleviate many of the questions that may be raised by checking supervisory staff and regulatory authorities etc.

Using the engineer's structural mark up information the drawings and details should be prepared by the designer to show support for all these loads. Particular attention should be paid to larger point loads, making sure all stud posts align down through the timber frame from roof level to foundation. Floor zones should be fully blocked under these posts.

The regular load-bearing studs should align down the building unless sufficient provision is made to spread the load at floor zone levels. The effect of uplift wind loads should be accounted for at all levels and detailed with appropriate fixings etc.

22. Foundations

22.1 Overview

Foundations are required to spread the dead and imposed loads from a building onto the ground beneath without excessive deflection or exceeding the safe bearing stress for the type of soil.

The appropriate foundation type is dependant upon a number of factors:

- bearing capacity and variability of the soil
- structural form of the building
- ability of the building to accommodate differential settlement.

When designing foundations for timber frame construction it is important to give prior consideration to the sequence of construction.

Ideally, the components of the timber kit should be located and installed upon delivery to handling and storage. In order for this to occur it is necessary for foundations, soleplate and scaffolding to be completed prior to delivery.

Where timber frame components are manufactured offsite then assembled on site accuracy is key - it is critical that the foundations are accurate, square and level.

22.2 Common foundation types

22.2.1 Strip foundations

Strip foundations are a continuous strip of concrete which support a line of loads, most commonly a structure's load-bearing walls or a line of columns at close centres where using pad foundations would be inappropriate.

The depth and width of strip foundations will vary depending on the soil conditions, wall dimensions and specification, type of structure and storey height.

Strip foundations may be mass concrete or reinforced. They are the most common type of foundation used for small buildings.

22.2.2 Trench fill foundations

Because of the relatively light load timber frame structures impose on foundations, they can often be supported upon narrow mass concrete foundations on soils of low bearing pressure. These foundations however cannot be less than the width of the foundation wall.

For trench fill foundations narrow trenches are excavated to the required depth and filled with concrete. Trench fill foundations are usually excavated once the top soil has been removed or a level surface has been provided. It is critical that the top of the concrete is accurate and level.

The decision to us trench fill over strip foundations will typically come down to cost, soil condition and/or preference.

22.2.3 Raft foundations

Raft foundations are a reinforced concrete slab or raft which extends over the entire loaded area. They may be stiffened by ribs or beams incorporated into the foundation where appropriate.

Raft foundations are used to spread the load from a structure over a large area, most typically the entire area of the structure, and are designed to accept ground movement, essentially allowing the structure to float on the soil. Raft foundations have the advantage of reducing differential settlements as the concrete slab resists differential movements between loading positions. They are often needed on soft or loose soils with low bearing capacity as they can spread loads over a larger area.

They may also be used when column loads or other structural loads are close together and individual pad foundations would interact.

22.2.4 Pad foundations

Pad foundations are used to support an individual point load such as that due to a structural column. They may be circular, square or rectangular. They usually consist of a concrete block or slab of uniform thickness. For timber frame structures, they are most commonly used to support isolated columns, such as those at ground floor level supporting projecting upper floors.

22.2.5 Pile foundations

Piles are often used because adequate bearing capacity cannot be found at shallow enough depths to support the structural loads. It is important to understand that piles get support from both end bearing and skin friction. The proportion of carrying capacity generated by either end bearing or skin friction depends on the soil conditions. Piles can be used to support various different types of structural loads.

Piles may be hammer driven into the ground, in which case they are usually made from steel or pre-cast concrete, or bored using a rotating auger and made from cast insitu concrete. In the past, timber was widely used for driven piles.

In order for the loads from the building to be transferred to the piles it is usual to place reinforced concrete ground-beams beneath the walls spanning between the piles.

22.3 Soil improvement

The foundations design and type will be informed by a ground conditions investigation survey. As an alternative to using more sophisticated foundation types, there are ways that the soil can be improved, usually by increasing its density. The bearing capacity may be increased and/or the tendency to compress under load reduced by various methods, often patented, some of which are described below.

22.3.1 Vibroflotation

Vibroflotation involves the use of a vibrating probe that can penetrate granular soil to depths of over 30 m. The vibrations of the probe cause the grain structure to collapse thereby densifying the soil surrounding the probe.

22.3.2 Dynamic compaction

Densification is performed by dropping a heavy weight of steel or concrete in a grid pattern from heights of 10 to 30 m.

22.3.3 Stone columns

Columns of gravel constructed in the ground. Stone columns can be constructed by the vibroflotation method. They can also be installed in other ways, for example, with help of a steel casing and a drop hammer. In this approach the steel casing is driven in to the soil and gravel is filled in from the top and tamped with the drop hammer as the steel casing is successively withdrawn.

22.3.4 Grouting

A technique whereby a slow-flowing water/sand/cement mix is injected under pressure into a granular soil. The grout forms a bulb that displaces and hence densifies the surrounding soil.

22.4 Foundations design regulations

Simple design rules for strip foundations are given in the following publications and associated documents referenced within:

- England and Wales: Approved Document A (Structure)
- Scotland: Technical Handbook Section 1 (Structure)
- Northern Ireland: Technical Booklet Part D (Structure)
- BS EN 1992 Eurocode 2: Design of concrete structures
- BS EN 1997 Eurocode 7: Geotechnical design
- NHBC Standards, Part 4 (Foundations)
- BS 8103-1 Structural design of low rise buildings. Code of practice for stability, site investigation, foundations, pre-cast concrete floors and ground floor slabs for housing.

Please note that these are only applicable for buildings and site conditions meeting the conditions set out within each of the documents.

These should be read in conjunction with the relevant associated documents. It is essential to have an understanding of the requirements for foundations in timber frame construction.

In some cases, foundations may be constructed, covered with earth to aid logistics on site, and then be uncovered at a later stage in construction.

23. Introduction to steelwork

23.1 Overview

Although it is desirable to limit the amount of structural steel in a timber frame building, if only because it usually has to be sourced from an external supplier, there are instances where it is used:

- where the size of a structurally equivalent timber member would be too large to physically fit within the space available (for example a large span floor beam that has to be within the depth of the floor zone).
- to provide support for masonry
- to provide portal frames that have resistance against racking forces (it is possible to produce these in timber but the provision of moment resisting connections is usually problematic).

Structural steelwork should be designed in accordance with BS EN 1993 (Eurocode 3).

23.2 Applications

Steel elements may be necessary in timber frame design where the structural properties of timber and engineered timber products are insufficient to deal with the loads required in the building. Some examples of such applications are:

- in an apartment block where there is a change in the apartment layouts from one floor to the next. Steel beams may be necessary in the lower apartment to support loads from above.
- in modular timber frame construction in the corners of the module to provide extra rigidity and racking resistance
- specialist steel connectors may be used in complex timber trusses, or with use of large-sections engineered timber products.

Activity

What timber frame steelwork connection details are used at the company you work?

Further reading

McKenzie, W.M.C. (2015). Design of Structural Elements. Palgrave: 2nd edition.

24. Typical timber frame kit

24.1 Overview

Below is an example of a common timber frame structure.

Note that there are many alternative build methods and systems available as described in earlier sections.

This section serves only to offer a basic understanding of what may be involved and the common elements which a typical (open panel, platform frame) timber frame structure might comprise.

You should obtain further details from the company in which you work and ensure that you are familiar with the methods and systems they employ.

It is also helpful for you to gain an understanding and appreciation of the build methods and systems employed by others in the timber frame sector.

24.2 Soleplates

- Damp proof course (DPC)
- Solid timber, width as per wall panel bottom rails
- Fixing types
- Packing

24.3 Ground floor

24.3.1 Suspended ground floor

- Ground cover
- Membranes
- Rim board/header members
- Floor joists
- Joist hangers and connectors
- Noggings, blocking
- Insulation w/supporting mesh or similar. Rigid insulation supported on battens
- Floor deck
- Floor finish

24.4 First floor

24.4.1 Intermediate floor

- Rim board/header members
- Floor joists
- Insulation if appropriate for acoustic performance
- Stairwell trimmers
- Joist hangers and connectors
- Restraint straps
- Noggings, blocking, strutting
- Floor deck
- Floor finish
- Ceiling lining

24.4.2 Separating floor

- Rim board/header members
- Floor joists
- Insulation (between joists and between floor battens)
- Joist hangers and connectors
- Restraint straps
- Noggings, blocking, strutting
- Floor deck
- Floor battens
- Gypsum 'plank'
- Floor finish
- Flanking strip

As well as providing a means to accurately locate the structure soleplates are the means of transferring loads to the foundations.

24.5 External wall panels

- Studs
- Rails
- Noggings
- Head binder
- Top and bottom rails for openings
- Sheathing (external/cavity)
- Insulation
- Lining (internal)
- Membranes
- Tie-down straps
- Wall ties
- Lintel
- Cavity barriers

External cladding may be brick, block with a cement render, tiles, slates, timber boards, render on battens, timber or metal panel or system specific render systems with integrated insulation or similar system.

24.6 Internal wall panels

There can be little difference in the construction of load-bearing and non-load-bearing internal wall panels. One significant difference is in the head detail of load-bearing wall panels.

It is good practice to have non-load-bearing panels lower than load-bearing panels, to prevent attracting load from the floors. This will also enable installation of the wall panels after the floors are installed.

When compared to load-bearing walls, the section size of the timber studs and rails which form the frame for non-load-bearing walls may be of a smaller section size though they typically remain the same for reasons of manufacture and standardisation. Additional studs may be required in load-bearing panels to support and transfer loads in accordance with structural calculations.

Party walls are typically formed by two independent leaves / frames, each of a similar construction to internal walls, separated by a cavity. The overall width of the party wall must be as specified by the architect. Typically, the only connection between both leaves will be at the head of the wall with a party wall strap. Party walls typically incorporate additional and/or denser wall linings for fire resistance and acoustic performance. The cavity between the leaves may or may not be insulated, subject to the architects specification.

24.6.1 Load-bearing internal wall panels

- Studs
- Rails
- Noggins
- Head binder
- Lintel (above door openings)
- Insulation
- Linings

24.6.2 Non-load-bearing internal wall panels

- Studs
- Rails
- Noggins
- Head binder (for continuity)
- Insulation
- Linings

24.6.3 Party walls

- Studs
- Rails
- Noggings
- Head binder
- Sheathing
- Insulation (between stud

Party wall width
According to best practice at the Robust Details, the width of the party wall should be 250mm.

bays and in the cavity where appropriate)
- Cavity barriers (where specified)
- Fire stops
- Netlon mesh
- Bracing
- Party wall straps

24.7 Roof structure

24.7.1 Trussed rafter roof
- Fink trusses
- Noggins
- Truss clips
- Truss shoes
- Framing anchors
- Tie-down straps
- Restraint straps
- Gable ladders
- Bracing
- Sarking
- Membranes
- Counter battens
- Tile battens
- Fascia boards
- Soffit framing
- Soffit panels

24.7.2 Gable end
- Spandrel panel
- Gable ladder

24.7.3 Hip end
- Girder truss
- Hip trusses
- Hip rafters / boards
- Mono trusses
- Trim rafters

24.7.4 Valley
- Valley trusses
- Valley rafters/boards

24.7.5 Sundries
- Insulated ceiling hatch
- Meter board and hot water cylinder plinth

Some panels may be lifted and positioned by hand.

Reflective breather membrane.

Roof truss construction. Donaldson Timber Engineering

25. Common materials and components

25.1 Overview

This section lists some common materials and components used for timber frame construction which you are likely to encounter. It is important for you to become familiar with the items that the company in which you work uses.

Even if you do not typically use some of these items it is important that you are at least aware of them.

More detailed information about the majority of these materials, their characteristics and advantages, can be found in earlier sections of this workbook.

Activity

Which common materials and components for timber structures are used at the company you work?

25.2 Timber, EWP and wood based products

- Solid timber
- I-joists
- Open web joists
- Box beams
- Glued laminated timber (Glulam/GLT)
- Laminated Veneer Lumber (LVL)
- Parallel Strand Lumber (PSL) / Laminated Strand Lumber (LSL)
- Cross laminated timber (CLT) and variations of CLT:
    - Nailed cross laminated timber (NCLT)
    - Interlocking cross laminated timber (ICLT)
- Nail laminated timber (NLT)
- Dowel laminated timber (DLT)
- Structural insulated panels (SIPs)
- Timber cladding
- Trusses:

- Fink
- Attic
- King post
- Queen post
- Howe
- Fan
- Double W
- Hip
- Half hip
- Mono
- Asymmetric
- Valley frame
- Short/long cantilever
- Stub
- Top hat
- Raised tie
- Raised tie mono
- Vaulted ceiling
- Scissor
- Barrel
- Parallel chord
- Pagoda
- Stepped ceiling
- Combination
- Specials

25.3 Panel/sheathing products

- Oriented strand board (OSB)
- Plywood
- Particle board/Chipboard
    - Cement particle board
    - Flax-board
- Magnesium Oxide (MgO)

25.4 Metalwork

A number of manufacturers produce a wide range of metalwork products designed specifically for timber frame construction, and to suit the dimensions of common timber and engineered wood products. The manufacturers' literature provides safe working loads for their products and often includes guidance on correct installation to ensure that they are used as intended and installed in accordance with the manufacturers' instructions.

Bespoke connectors or 'specials' are typically available upon request but have longer lead times as they are not stock items and must be designed and fabricated prior to delivery.

When using these products, it is important that they are fixed as specified, using the correct fastener type and specification, and that members are correctly seated within the product. Incorrect installation may significantly reduce the product's performance.

Most structural fasteners and metal work are hot dipped galvanised or manufactured from pre-galvanised steel. It should be noted that not all alternative anti-corrosion treatments used on commonly available fasteners give an equivalent protection.

- Joist hangers
    - Face fix
    - Top fix
    - Light, medium and heavy duty
    - I-joist specific
    - Open web beam specific
    - Truss shoes
    - Skewed
    - Specials
- Clips for multiple members
- Clips for noggings
- Restraint straps
- Tie-down straps
- Party wall straps
- Truss clips
- Nail plates
- Sole plate anchors

When using fastener products, it is important that they are fixed as specified, using the correct fastener type and specification.

- Angle brackets
- Framing anchors
- Wall ties – standard and high movement

25.5 Fasteners and fixings

- Screws
  - Wood-screws
  - Structural screws
  - Plasterboard screws
  - Sheathing screws
- Nails
  - Plain
  - Annular ring shank
  - Square twist
- Staples
- Bolts
- Dowels
- Masonry fixings
- Steel fixings
- Toothed plate connectors

Activity

List three types of metalwork your company and describe their application.

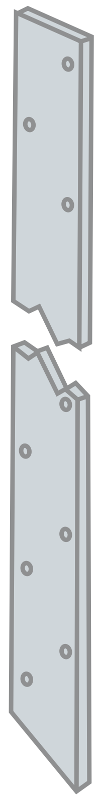
25.5.1 Fasteners - factors affecting strength

- **Fastener diameter:** the greater the fastener diameter generally the greater the load that may be carried, subject to maintaining the appropriate end and edge distances and spacings
- **Member thickness/fastener penetration depth:** increasing member thickness or fastener penetration depth will increase the strength of the fastener
- **Density of material:** generally, the performance of fasteners increases as the density of timber into which they are fixed increases
- **Angle of load to grain:** the values for fasteners other than nails or screws are dependant upon the angle between the applied force and the grain of the timber. The maximum capacity is achieved when the force is parallel to the grain, the minimum when it is perpendicular. At angles between these extremes an intermediate value may be calculated
- **Fixing into end grain:** fixing into the end grain rather than side grain vastly reduces the fastener capacity, particularly in withdrawal

- **Fastener spacing and distance to end and edge of the timber:** in order to achieve optimum performance it is necessary to maintain an adequate distance between the fasteners and ensure that they are not positioned too close to the edge or end of the timber.

Activity

Which factors affect the strength of fasteners?



Restraint strap

25.6 Membranes

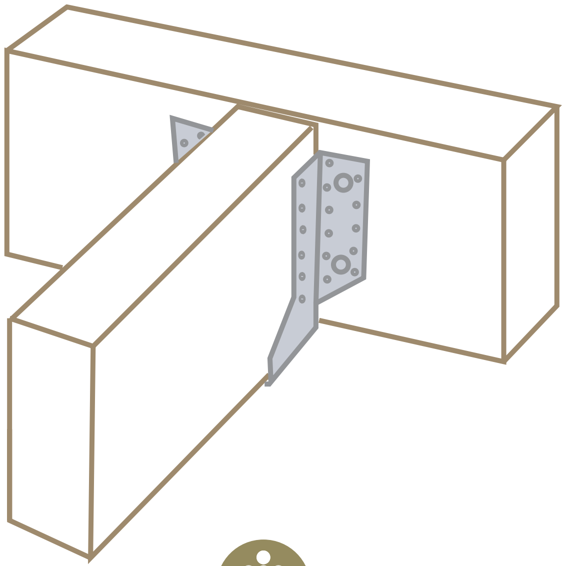
- Damp proof course
- Vapour control layer
- Air barrier
- Breather membrane

25.7 Sundries (by others)

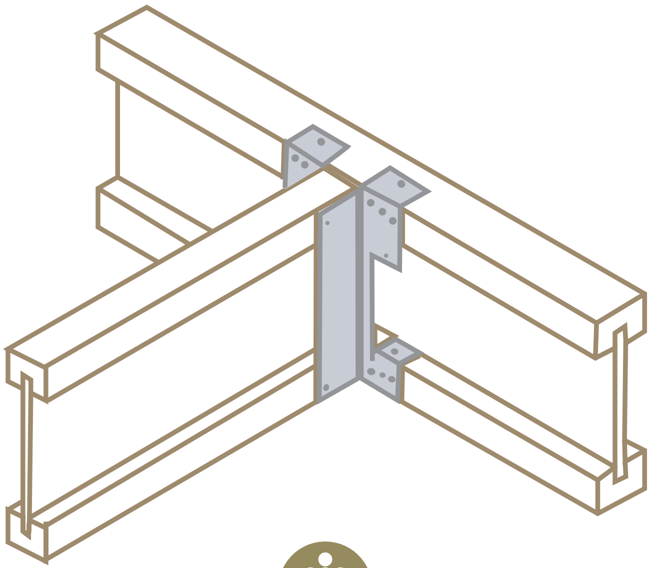
- Weep vents
- Cavity trays
- Cavity barriers (by timber frame)
- Lintels
- Loft access doors
- Flashings

25.8 Finishes (by others)

- External walls
  - Brick
  - Block and render
  - Timber cladding
- Internal walls
  - Plasterboard
- Roofs
  - Concrete tiles
  - Clay tiles
  - Natural slates
  - Fibre cement slates



Face fix hanger



Top fix hanger

Timber joist hanger

26. Quality checks

26.1 Overview

Throughout production it is important that checks are made to raw materials, components and completed assemblies to ensure that they meet requirements.

It is important that a system exists which enables effective monitoring and checking of resource, process and outgoing products to ensure quality and consistency and that whatever is produced in the factory complies with the drawings, specifications and standards.

Production drawings should include all references to the materials used in the manufacture, all information necessary for correct fitting and assembly and include allowable tolerances where appropriate.

The manufacturer should establish documentation and implement controls to ensure that processes are in accordance with specifications, standards, and requirements and that the products which it manufactures continually conform to the specifications and meet the performance criteria that they declare.

Factory production control (FPC) provides documented, permanent and internal control of production which is robust, traceable and repeatable and ensures quality and consistency for process and product, and ultimately good service to the customer.

An FPC system typically forms part of the quality management system (QMS) and is underpinned by the quality plan.

Typically, an FPC system will comprise at the very least:

- a suite of standard procedures, supporting documentation and records to standardise operations, identify products, state and monitor how products are manufactured and ensure safe methods of operation at all times
- controls to monitor and check incoming resource prior to assembly
- controls to monitor and check products during and post assembly prior to being delivered to site
- regular internal and external auditing to monitor the effectiveness of the system and quality and consistency of the manufacturing process and manufactured items
- means to enable corrective and preventive actions for control of non-conforming products to ensure that immediate action is taken to rectify any inconsistencies or non-compliances
- means to control procurement ensuring materials, components and equipment are correct and purchased from approved suppliers
- intermediate testing of products off the line to ensure that declared performance and specification are continually met
- maintenance schedules and standard procedures for correct handling of machinery and equipment
- standard procedures for correct handling of materials and assemblies
- personnel training and competency records – roles and responsibilities.

Factory production control (FPC) provides documented, permanent and internal control of production which is robust.

26.2 Materials check

Raw materials and components should be checked against drawings and specifications upon receipt and throughout the manufacturing process in accordance with the standard procedure(s) to ensure that they meet the required specification. Checks should be methodical and repeatable for all similar items and the results recorded on a standard checklist. When checking items it is important to know the criteria and any tolerances against which they are to be checked to ensure that items which do not comply are identified, enabling action to be taken to rectify the non-compliance.

Examples of typical materials checks undertaken during timber frame manufacture are given below:

- Specification: checks are made to ensure that the materials used are of the correct specification
- Moisture content: checks are made at various locations using a calibrated moisture meter to ensure that the moisture content of timber and wood-based materials is within tolerance
- Dimensions: checks are made to ensure that the dimensions are in accordance with the specification and within tolerance
- Treatment: checks are made to ensure that the material has been treated with preservative, fire retardant and/or water repellent as appropriate
- Defects: checks are made to identify any defects or damage that is likely to have a negative impact upon performance, ease of installation or aesthetics
- Quantities: items are counted to ensure the correct quantity has been received or produced
- Ancillaries: checks are made to ensure that ancillary components e.g. connectors, ties, membranes and fasteners, are present and of the correct specification.

Activity

Why is it important to check materials and components?

26.3 Assembly check

Assemblies should be checked against drawings and specifications throughout the manufacturing process in accordance with the standard procedure(s) to ensure that they meet the required specification. Checks should be methodical and repeatable for all similar assemblies and the results recorded on a standard checklist. When checking assemblies it is important to know the criteria and any tolerances against which they are to be checked to ensure that assemblies which do not comply are identified, enabling action to be taken to rectify the non-compliance.

Examples of typical general and specific assembly checks undertaken during timber frame manufacture are given below:

- **Overall dimensions:** checks are made to ensure that the major dimensions are in accordance with the drawings and specification and within tolerance
- **Squareness:** corners and intersections are checked and diagonal dimensions taken to ensure that elements and apertures are square and correct
- **Apertures:** checks are made to ensure that the location and dimensions of window and door openings are in accordance with the drawings and specification and within tolerance. Where installed in the factory the specification and installation of sills, doors and windows should be inspected to ensure compliance with the drawings and specification
- **Stud, joist and/or rafter centres:** checks are made to ensure the position of and centre to centre distances between beams are in accordance with the drawings and specification
- **Junctions:** checks are made to ensure that junctions are properly formed and in accordance with the drawings and specification.
- **Expansion joints:** checks are made to ensure that expansion joints are properly formed and in accordance with the drawings and specification
- **Defects and/or damage:** checks are made to identify any defects and/or damage that may have occurred during assembly which is likely to have a negative impact upon performance or aesthetics
- **Structural components:** checks are made to ensure structural components i.e. lintels, are of the correct specification, positioned correctly and have been properly installed
- **Sheathing:** checks are made to ensure that sheathing boards are correctly fixed, positioned and in the correct orientation with adequate gaps between boards as appropriate. Fasteners should be flush within the surface with none protruding or over-driving
- **Cladding:** checks are made to ensure that cladding is correctly positioned, oriented and installed
- **Floor deck:** checks are made to ensure that all edges are adequately supported (no flying joints) and that there are no protruding fastener heads - nails should be punched and screws countersunk. If adhesives are used checks should be made to ensure that it has been applied correctly in the correct locations
- **Fasteners:** checks are made to ensure that fasteners are positioned correctly and accurately, centre to centre distances are correct and that edge and end distances have been adhered to. Fasteners should not be over driven or protruding. Where appropriate i.e. for floor decking, fasteners

Activity

What other assembly checks might be undertaken and why? Give specific examples relevant to a project in which you are involved

should be punched just below flush or countersunk

- **Membranes and seals:** checks are made to ensure that membrane layers and seals are of the correct specification, have been correctly positioned and installed, and that there are no punctures or tears. Checks are made at the locations of joints, junctions and corners to ensure that membranes are correctly lapped as appropriate
- **Insulation:** checks are made to ensure that insulation is of the correct specification and thickness, has been correctly installed and that care has been taken to ensure that voids are fully filled and there are no gaps
- **Ancillaries:** checks are made to ensure that any ancillary items are of the correct specification, have been properly installed and are in the correct position
- **Services:** when fitted in the factory checks are made to ensure that services and service boxes are of the correct specification, have been properly installed and correctly routed.

26.4 Quality control

It is common for timber frame manufacturers to establish, document, implement and maintain a Quality Management System (QMS) to ensure quality and consistency of the products which they manufacture to continually meet performance criteria and customer requirements.

A QMS details the organisational structure, policies, procedures and resources necessary for the implementation of effective quality control, in accordance with the requirements of recognised standards, to ensure that defined targets are continually achieved.

A QMS will typically comprise and focus upon the following elements:

- documentation
- policies
- management
- customer focus

- planning
- documented processes and procedures for manufacture
- roles and responsibilities, authority and communication
- resource management
- human resources
- infrastructure
- work environment
- design, development and product realisation
- procurement and provision of services
- equipment
- monitoring and measurement
- control of non-conformities/non-conforming product
- continuous improvement

among others.

Timber frame manufacturers typically operate a QMS to ensure that their products are of consistently high quality and that their customers are satisfied that the product which they are purchasing is fit for purpose and in accordance with the specification.

Measuring the quality of a product and detecting any changes to the quality are both important features of the quality control process.

As timber frame components are manufactured in a factory they lend themselves well to strict quality control. This is a significant advantage when compared to traditional masonry construction on site.

It is important to familiarise themselves with the parts of the QMS relevant to their role and to ensure that it is always adhered to.

There are a number of product certification schemes for construction products.

It is important for staff to be aware of the product certification scheme and associated standards to which the company in which they work operates under and is certified to, if any.

27. Regulations, standards and certification schemes

In order that buildings are constructed in a safe and durable manner using approved materials, products and components, various standards are set, both by government and private organisations, some of which are mandatory and others voluntary. Certification schemes and products approvals ensure and guarantee the quality of the construction product.

Compliance with relevant regulations and standards is compulsory on all projects. It is vital that the timber frame designer is familiar with the certification schemes used by their company and that they have a good working knowledge of the relevant and current building regulations and standards.

27.1 Building regulations

The Building Regulations exist to ensure the health and safety of people in and around all types of building (domestic, commercial and industrial). They also provide for energy conservation, suitable access and use of buildings.

They define the technical performance of building work. For example:

- set out notification procedures to follow when starting, carrying out and completing building work
- set out the requirements with which the individual aspects of building design and construction must comply.

27.1.1 Approved Documents – England and Wales

For additional information and to assist with complying with the Building Regulations a series of Approved Documents (AD) are available:

AD A	Structure
AD B	Fire safety
AD C	Site preparation and resistance to contaminates and moisture
AD D	Toxic Substances
AD E	Resistance to sound
AD F	Ventilation
AD G	Sanitation, hot water safety and water efficiency
AD H	Drainage and waste disposal
AD J	Combustion appliances and fuel storage systems
AD K	Protection from falling, collision and impact
AD L	Conservation of fuel and power
AD M	Access to and use of buildings
AD P	Electrical safety
AD Q	Security in dwellings
AD R	High speed electronic communications networks
AD 7	Material and workmanship

27.1.2 Technical Handbooks – Scotland

The Building Standards (Scotland) Regulations are legal requirements laid down by the Scottish Parliament that are intended to provide reasonable standards for the purpose of securing the health, safety, welfare and convenience of people in and around buildings, for conserving fuel and power and for furthering the achievement of sustainable development.

The functions of the Building Standards (Scotland) Regulations are:

- to prepare the building regulations and write guidance on how to meet the regulations
- to provide views on compliance to help verifiers make decisions
- to grant relaxations of the regulations in exceptional cases
- to maintain a register of Approved Certifiers
- to monitor and audit the certification system
- to monitor and audit the performance of verifiers
- to verify Crown building work

Further information:

www.gov.scot/Topics/Built-Environment/Building/Building-standards/BSD

Two Technical Handbooks are published and updated with guidance on compliance with the Building Standards (Scotland), domestic and non-domestic handbooks.

These publications follow the same structure:

Part 0	General
Part 1	Structure
Part 2	Fire
Part 3	Environment
Part 4	Safety
Part 5	Noise
Part 6	Energy
Part 7	Sustainability

27.1.3 Technical Booklets – Northern Ireland

In Northern Ireland, Technical Booklets are published and updated with guidance on compliance with the building regulations.

Because the information is updated frequently, the number and titles listed here may change, but in general the Technical Booklets are as follows:

TB B	Materials and workmanship
TB C	Site preparation and resistance to contaminants and moisture
TB D	Structure
TB E	Fire Safety
TB F1	Conservation of fuel and power in dwellings
TB F2	Conservation of fuel and power in buildings other than dwellings
TB G	Resistance to the passage of sound
TB H	Stairs, ramps, guarding and protection from impact
TB J	Solid waste in buildings
TB K	Ventilation
TB L	Combustion appliances and fuel storage systems
TB N	Drainage

TB P	Sanitary appliances, unvented hot water storage systems and reducing the risk of scalding
TB R	Access to and use of buildings
TB V	Glazing

27.2 BS ENs and Eurocodes

The European Standards (ENs) are applicable across the single European market countries and are used to enable trade between these countries through a uniform standard.

Each European single market country, including the UK, adopts the EN standards in its home language and standard system. In the UK this is in the form of British Standards (BS ENs).

More recently, the European Structural Eurocodes have been made applicable in the UK.

The Eurocodes comprise 10 European standards in 58 parts, including National Annexes, which provide the basis for structural and geotechnical design within the EU. These superseded existing national standards in March 2010.

The Eurocodes provide:

- design criteria and methods of achieving the necessary requirements for mechanical resistance, stability and resistance to fire
- a common understanding of the design of structures.
- a framework for creating harmonised technical specifications for CE marking of construction products in accordance with the Construction Products Regulation.

The Eurocodes provide uniform structural design guidance across the European Union countries. Similarly to ENs, the UK complies with the Structural Eurocodes through import into BS ENs, whose structure and timber frame standards are listed below. The learner is advised to consult the most up-to-date standard relevant to their specific design for every project, as the standards are frequently updated. Moreover, a flowchart for timber frame design has been provided within the Eurocodes, shown below.

In the Eurocodes the structural design in buildings is defined as being either within limit states and therefore safe and satisfactory, or out with limit states and therefore unsafe and unsatisfactory. There are two types of limit states.

Ultimate limit states (ULS): associated with forms of structural failure or collapses relevant to safety conditions.

Serviceability limit states (SLS): associated with normal service conditions, such as deflection and vibration; relevant to comfort and appearance conditions

Eurocode 0:	Basis of Structural design
Eurocode 1:	Actions on Structures
Eurocode 2:	Design of Concrete structures
Eurocode 3:	Design of Steel structures
Eurocode 4:	Design of Composite Steel and Concrete structures
Eurocode 5:	Design of Timber structures

BS EN 1995-1-1:2004+A1:2008 Eurocode 5. Design of timber structures. General. Common rules and rules for buildings

NA to BS EN 1995-1-1:2004+A1:2008 (National Annex)

BS EN 1995-1-2:2004 Eurocode 5. Design of timber structures. General. Structural fire design

NA to BS EN 1995-1-2:2004 (National Annex)

BS EN 1995-2:2004

Eurocode 5. Design of timber structures. Bridges

NA to BS EN 1995-2:2004 (National Annex)

Eurocode 6: Design of Masonry structures

Eurocode 7: Geotechnical Design

Eurocode 8: Design of structures for earthquake resistance

Eurocode 9: Design of aluminium structures

In connection with timber frame design, the following British Standards are also used in industry:

BS 5268-3:2006. Structural use of timber. Code of practice for trussed rafter roofs

BS 5268-6.1:1996. Structural use of timber. Code of practice for timber frame walls

BS 5268-6.2:2001. Structural use of timber. Code of practice for timber frame walls. Buildings other than dwellings not exceeding four storeys

BS 5268-2:1990. Structural use of timber. Recommendations for the calculation basis for span tables. Purlins supporting rafters

BS 8417:2011+A1:2014 Preservation of wood. Code of practice

BS 8103-3:2009 Structural design of low-rise buildings. Code of practice for timber floors and roofs for housing

BS 6399-2:1997. Loading for buildings. Code of practice for wind loads

27.3 National House Building Council (NHBC)

The NHBC is a standard setting body and leading warranty and insurance provider for new dwellings in the UK.

A 10 year warranty and insurance policy is provided to new home buyers.

Key services provided:

- a register of builders and developers who agree to comply with the NHBC Rules and Standards
- setting and maintaining construction standards for new homes
- consultancy and testing of acoustics, air leakage, energy, sustainability and health and safety
- inspecting at key stages of new home construction
- providing building control services in England and Wales
- providing a ‘Buildmark’ warranty and insurance policy for new homes
- providing technical and engineering advice
- produce a Housing Market Report and other information

publications

- provide training on health and safety and technical topics
- publish standards including the Quality Management Services (QMS) and Construction Quality Reviews (CQR).

The NHBC Standards provide guidance on meeting the technical requirements and recommendations for external and internal timber frame walls, flat and pitched roofs and both solid and engineered joist floors.

www.nhbc.co.uk/Builders/ProductsandServices/TechZone/nhbcstandards/

27.4 Local Authority Building Control (LABC)

LABC is the largest building control service in England and Wales with 3,000 building control surveyors and a 75% market share across all building sectors.

LABC represent all local authority building control teams in England and Wales. Their members work co-operatively with building owners, home owners, architects, plan drawers, developers, building contractors and other professionals to ensure buildings are safe, healthy and efficient to meet the standards set by the building regulations.

Local Authority Building Standards Scotland (LABSS) represent Scotland's 32 local authority building standards services. Their members work in local authorities and aim to protect the public interest by ensuring that all new buildings and those being altered, extended or converted comply with the building regulations and technical standards.

LABC Warranty and Premier Guarantee work in partnership with LABC throughout England and Wales to provide new home and structural warranties.

https://www.labc.co.uk/

27.5 Exova BM TRADA Q-Mark

The BM Trada Q-Mark is a product guarantee system, which certifies the building products quality of manufacturing, handling and compliance with regulations. There are several schemes under the BM Trada Q-Mark:

- Acoustic window
- Building insulation products
- Building systems
- Construction certification
- Engineered floor products
- Engineered wood products
- Engineering & design protocol
- Enhanced lifetime performance of doors
- Enhanced security door
- Enhanced security window
- Fire door manufacture
- Flat glass
- High performance timber window
- Insulating glass units
- Marine plywood
- Paint application
- Solid wood panelling & cladding
- Timber frame elements
- Timber tiling batten
- Trussed rafter
- Window general performance
- Wood based panels
- Wood flooring

Further information:

www.exovabmtrada.com/en-gb/certification/

Further Reading:

BM TRADA.
Site Check pocket book

27.6 Trussed Rafter Association (TRA)

The TRA represents trussed rafter manufacturers throughout the UK.

Its aims are:

- to encourage architects, engineers and specifiers to choose trussed rafters
- to offer expert advice and technical information on trussed rafters
- to implement common design and safety standards
- to develop the professional status of members and their employees
- to provide marketing activities, which promote the benefits of trussed rafters
- to support members through a range of services

Further information:

www.tra.org.uk

27.7 Construction Products Regulation (CPR)

The CPR is a legislative document governing the introduction of construction products into the market. The CPR lays down the conditions for sale and supply of construction products in the EU and harmonises the methods of testing, declaration of a product's performance and the assessment of verification of constancy of performance.

The CPR outlines the responsibilities of parties involved e.g. manufacturers, importers, test labs, certification bodies and:

- breaks down technical barriers to trade and allow free movement of goods in the EU
- provides a system of harmonised technical specifications to establish harmonised requirements for product performance
- installs a framework of Notified Bodies
- enables CE marking of products.

The CPR outlines the Basic Requirements for Construction Works (BRCW), separated in to 7 essential characteristics which are to be assessed as appropriate for each specific product:

- Mechanical resistance and stability
- Safety in case of fire
- Hygiene, health and the environment
- Safety and accessibility in use
- Protection against noise
- Energy economy and heat retention
- Sustainable use of natural resources

Note that some characteristics may not apply to the particular product's end use.

The only way to demonstrate that a product complies with the CPR is by applying the CE marking.

27.8 CE Marking

CE marking for products covered by a harmonised standard (hEN), or conforming to a European Technical Assessment (ETA) issued for the product, became mandatory across the EU from 1st July 2013.

The CE marking is a key indicator of a product's compliance with relevant standards, essential requirements and EU legislation.

The CE marking is a regulatory mark which must be affixed prior to product placement on the market.

CE marking:

- applies to all products covered by a harmonised standard (hEN) or a European Technical Assessment (ETA)
- signifies that a product conforms with all EU directives or regulations that apply to it
- process which a product undergoes to verify that it is fit for a specific purpose
- it is not a statement of quality but rather a declaration confirming that the product is fit for purpose and has been subject to measures to ensure that's the case
- allows unsafe products to be removed from the market
- applies to all countries in the European Economic Area (EEA)
- facilitates free movement of goods by eliminating technical barriers to trade and administrative burdens for circulation of goods in the EEA.
- doesn't indicate that the product was manufactured in the EEA but that it has been appropriately assessed before being placed on the market.

CE marking is the responsibility of the manufacturer or authorised representative i.e. importer or distributor.

Not all products require CE Marking, only those subject to relevant directives or regulations. Construction products are subject to the Construction Product Regulation or CPR.

The CE marking must be:

- accompanied with a Declaration of Performance (DoP) and supporting technical documentation
- marked upon the product (where practicable) and be visible, legible and indelible
- marked upon corresponding packaging and literature.

Voluntary markings in addition to the CE mark may be added but must fulfil a different function and mustn't cause confusion or reduce legibility.

27.8.1 Harmonised technical specifications

Harmonised Technical Specifications define the methods of assessing and declaring the relevant performance characteristics of the product. Standard assessment methods are agreed collectively by member states.

These may be either:

- Harmonised European Standards (hENs)
- European Assessment Documents (EADs).

Both hENs and EADs provide information on the regulated characteristics that a product must satisfy to enable CE marking.

hENs are developed and produced by the European Committee for Standardisation (CEN).

EADs are developed and produced for products which are not covered by hENs by the European Organisation for Technical Approvals (EOTA).

- Harmonised Technical Specifications contain, at least:
- a general description of the construction product and its intended use
- essential characteristics relevant for the intended use
- methods and criteria for assessing the performance
- principles for Factory Production Control (FPC).

27.8.2 Harmonised European

Standards (hENs)

An hEN is a published document containing technical information to define practice in a consistent, repeatable manner. They are international standards with an "ISO" and/or "EN" prefix.

The national standard "BS" refers to British Standards. As such "BS EN" (sometimes "BS EN ISO") is the UK version of a European harmonised standard.

Note however that not all BS ENs are hENs. A European standard is adopted by a European standards body but is not harmonised unless it is subject to a mandate and a reference is published in the Official Journal of the EU (OJEU).

hEN's are 'special' ENs which have an ANNEX ZA and enables a product in compliance with that EN to be CE marked.

Most products used in timber construction are now covered by hENs and as such must be CE marked.

Standards outline the requirements which must be met (and provide guidance on how to verify that products meet these requirements).

Annex ZA of an hEN contains clauses which address the provision of the CPR:

Annex ZA.1 defines product characteristics and clauses within the standard which outlines the test method(s)

Annex ZA.2 (AVCP) defines the process for conformity assessment and tasks to be undertaken by the manufacturer and Notified Body

Annex ZA.3 defines the process for CE Marking and labelling.

27.8.3 European Assessment Document (EAD)

An EAD may be developed for construction products which are not covered, or fully covered by an hEN. An EAD provides the basis for a European Technical Approval (ETA), enabling CE marking of products, and details how to meet requirements of the CPR.

An EAD may already exist where another manufacturer has applied for an ETA for CE marking of an identical or similar product. Under these circumstances, it is not mandatory to apply for an ETA and so CE marking of the product remains voluntary. Note if the manufacturer chooses to request an ETA, enabling them to apply the CE marking to their product, then it becomes mandatory for them to do so.

EADs have a section which serves the same function as Annex ZA of hENs.

27.8.4 European Technical Approval (ETA)

A ETA is meant for a manufacturer to CE mark a product where the product is not or not fully covered by an existing hEN or the product is already covered by an EAD.

An ETA is a document which provides information on the performance of a construction product, defines the product and its intended use and provides the basis for a Declaration of Performance to be drawn up by the manufacturer.

An ETA contains:

- general information on the manufacturer, product type, name and place of manufacture
- declaration of product performance and reference to methods used for assessment
- technical details necessary for the implementation of the AVCP system.

Activity

Which certification schemes and standards does your company comply with?

27.8.5 National product approvals

National approvals are an option where no hEN or EAD exists and the manufacturer wishes to certify their product, but doesn't want to apply for an ETA.

National approvals:

- supports a manufacturer's declaration
- provides increased confidence and provides reassurance for suppliers
- recognised by local authorities, building control, government departments, warranty providers
- accelerates market acceptance.

Under national approvals products still undergo a rigorous process including testing, inspection and monitoring.

Examples:

- BBA Agrément Certificate
- BM TRADA Q-Mark

27.9 Timber certification and grading

Third party consultancy and certification businesses provide certification on strength grades of timber and is therefore important for timber frame designers to be aware of. The services are the following:

- visual strength grading of softwoods and hardwoods
- machine strength grading of softwoods and hardwoods
- machine and visual strength grading of scaffold boards
- FSC/PEFC/Other Chain of custody for sustainable forest management, which includes:
    - access to markets
    - risk management
    - availability and choice
    - compliance with legislation
    - logo and label
    - business sustainability
    - traceability
    - CE marking
    - ginger jointing
    - ISO 9001 Quality

Management System (BS EN 9001)

- greater efficiency and consistent control of major business processes
- regulation of successful working practices
- increased customer satisfaction
- greater consistency in the quality of products and services
- ISO 14001 Environmental Management System (BS EN 14001)
- better management of environmental risks
- Increased access to new customers and business partners
- demonstration of legal and regulatory compliance
- overall cost savings in terms of consumption, waste and recycling
- OHSAS 18001

27.10 ISO 9001

If an organisation wants to demonstrate to clients and other stakeholders that their timber frame products and services are of consistent quality and that their processes are continuously improved, the timber frame company can decide to comply with ISO 9001. This international standard on quality management is commonly used by companies of all types, not only timber frame designers.

The scope of ISO 9001 covers the following general sections:

- context of the organization
- leadership
- planning
- support
- operation
- performance evaluation
- improvement.

Critical in quality and efficiency improvement is the **'Plan, Do, Check, Act'** cycle, which is applicable to all processes.

More information on quality management can be found in section **26.4 Quality Control.**

ISO 9001 is incorporated in the British Standards as:

BS EN ISO 9001:2015. Quality management systems. Requirements

Activity

Which are the benefits of National product approvals?

27.11 STA Certification Schemes

27.11.1 Site Safe

Site Safe has been developed by the Structural Timber Association (STA) to ensure its members work closely with principal contractors/ clients to give clear concise information and assistance to the principal contractor regarding fire safety on construction sites.

The STA expects its structural timber building system members - including manufacturers, fabricators and contractors - plus erector/ installer members (who may also work directly with principal contractors /clients), to adopt the principles of Site Safe and register all sites they are involved with.

SITE SAFE
ACCREDITED USER

www.structuraltimber.co.uk/members/why-use-an-sta-member/site-safe/

27.11.2 STA Assure

STA Assure is designed to benefit both clients and members by promoting the differing accreditations and quality standards held by individual STA member companies. This scheme offers reassurances to the construction community that STA members meet or even exceed current legislation and regulatory requirements. The STA Assure accreditation highlights the differing levels of quality procedures, management systems and product performance standards, together with external accreditations held by STA members.

STA ASSURE

www.structuraltimber.co.uk

28. Law

28.1 Overview

The legal system is divided into two categories - public and private law.

Public law involves a public authority and examples are constitutional law, administrative law and criminal law. Private law deals with the rights and duties between private individuals and examples are the laws of contract, tort, property and family. The laws of contract and tort are known as civil law.

Criminal law deals with offences against the state and the decision to prosecute lies with the Crown Prosecution Service, civil law deals with wrongs against an individual and the decision to proceed is taken by the victim.

An example of criminal law is the Construction Design and Management Regulations, whereas a legal dispute between a client and his builder is an example of Civil Law.

Criminal and civil law differs in the following ways:

- separate courts deal with each
- different procedures are used
- different standards of proof are required– beyond reasonable doubt in the case of criminal law and balance of probability for civil cases
- terminology
- punishment for criminal cases and remedy (e.g. damages) for civil cases.

The designer has a major responsibility under the Construction Design and Management (CDM) regulations, with regard to designing in safety as regards the construction process, through to the finished structure and its eventual demolition. This is potentially a criminal law issue.

28.2 Criminal law

The principal areas of criminal law which involve the designer are those which involve health and safety. This is covered by the appropriate Workbook.

28.3 Civil law

Designers will generally be involved with the laws of tort and contract.

Tort is a legal term that means civil wrong, as opposed to a criminal wrong. Somebody behaves 'tortuously' when they harm other people.

Unlike obligations created through a contract, the duties imposed under tort law are mandatory for all citizens.

The dominant action in tort is negligence, which is used to protect people's bodies and property, including non-tangible economic interests. Negligence is a tort which targets an unreasonable breach of duty by one person to another.

In tort, professionals involved in the construction, such as designers, engineers, surveyors, and any other specialists, are potentially liable for claims for financial loss as a result of negligent work, in relation to, for example, design, technical specifications, calculations, valuations and suchlike.

The four elements of negligence are:

- Duty of Care
- breach of that duty
- breach causing harm in fact
- breach also causing harm in law.

Aims and objectives of the law of torts:

- compensation for harm
- prevent the continuance or repetition of harm
- punishment of the wrongdoer
- deterrence
- justice
- restoration of unjust enrichment
- declaration of rights
- declaration of status.

A contract is an exchange of promises or an agreement between parties. Contract law is based on the Latin phrase 'pacta sund servanda' (literally, promises must be kept). Almost everyone makes contracts every day, and breach of a contract is recognised by the law and remedies can be provided. Contracts may be written or agreed verbally.

Offer and acceptance analysis is a traditional approach in contract law used to determine whether an agreement exists between two parties. An offer is an indication by one person to another of their willingness to contract on certain terms without further negotiations. A contract is then formed if there is express or implied agreement. A contract is said to come into existence when acceptance of an offer has been communicated to the offeror by the offeree.

All valid contracts must have the following elements:

- **Terms:** a set of clauses defining the exact set of promises agreed to
- **Mutual agreement:** there must be an express or implied agreement. The essential requirement is that there is evidence that the parties had each from an objective perspective engaged in conduct manifesting their assent, and a contract will be formed when the parties have met such a requirement
- **Consideration:** there must be consideration given by all the parties, meaning that every party is conferring a benefit on the other party or himself sustaining a recognizable detriment, such as a reduction of the party's alternative courses of action where the party would otherwise be free to act with respect to the subject matter without any limitation
- **Competent, adult Parties:** both parties must have the capacity to understand the terms of the contract they are entering into, and the consequences of the promises they make. For example, animals, minor children, and mentally disabled individuals do not have the capacity to form a contract, and any contracts with them will be considered void or voidable. Although corporations are technically legal fictions, they are considered persons under the law, and thus fit to engage in contracts
- **Proper subject matter:** the contract must have a lawful purpose
- **Mutual right to remedy**
- **Mutual obligation to perform**
- **Intention to create legal relationship:** there is a strict presumption for commercial agreements to be legally bound.

Domestic and social agreements are usually unenforceable.

28.4 Comparison of contract and tort

Similarities:

- both involve civil law obligations
- both may be remedied by damages
- both are dealt with by civil courts

Differences:

- to enter into a contract is voluntary, whereas tortuous liability is imposed
- a contract leads to a duty to a party, whereas tort is general
- a contract is strict, whereas tort is due to a fault
- a court action under contract law is due to not fulfilling promise, whereas in tort, it is due to carrying out an activity wrongfully
- object of damages – for a contract they may only recompense actual losses, whereas for a tort they are unlimited and possibly punitive.

29. Maths

29.1 Basic maths to solve problems

It is likely that you will have to apply some basic maths at various stages. Some useful reminders are given below:

- a rectangle is a four sided shape with opposite sides of equal length and all four corners at angles of 90°
- perpendicular means 'at right angles' e.g. each side of a rectangle or square has two other sides perpendicular to it
- squares are rectangles with four sides of equal length
- parallel lines remain at the same distance from one-another
- parallelograms are four sided shapes with two pairs of parallel sides
- acute angles are less than 90°
- obtuse angles are greater than 90° but less than 180°
- reflex angles are greater than 180°
- corresponding angles on parallel lines are equal
- alternate angles between parallel lines are equal
- the sum of angles on a straight line is 180°
- vertically opposite angles are equal
- the sum of angles in a triangle is 180°
- an isosceles triangle has two sides of equal length and two equal angles.

29.2 Pythagora's theorem

In a right-angled triangle the side opposite the right angle (90°) is the longest side - this is called the hypotenuse.

The square of the hypotenuse is equal to the sum of the squares of the other 2 sides.

This can be presented using the following equation, often referred to as the 'Pythagorean equation':

$$a^2+b^2=c^2$$

Where;

a = the length of one of the sides other than the hypotenuse

b = the length of the other side other than the hypotenuse

c = the length of the hypotenuse

If two of these lengths are known this equation can be used to determine the third.

For example, to determine the length of the hypotenuse where the length of the other two sides is known:

Where;

a=5 metres

b=10 metres

c=hypotenuse,length unknown

$$5^2+10^2 = c^2$$

So:

$$25 +100=c^2$$

So:

$$c^2=125$$

So:

$$c = \sqrt{125}$$

So:

$$c = 11.18 \text{ metres}$$

And, to determine the length of one side where the length of the hypotenuse and the other side are known:

Where:

a=8 metres

b=length unknown

c=12 metres

$$8^2+b^2 = 12^2$$

So:

$$64 + b^2=144$$

So:

$$b^2=144-64$$

So:

$$b = \sqrt{80}$$

So:

$$b = 8.94 \text{ metres}$$

One practical application of Pythagoras' Theorem may be to check that a panel, cassette or opening is square i.e. that all four corners have an angle of 90°. This can be determined by measuring across both diagonals and comparing the results – if both diagonal measurements are equal then the angles at the corners must be 90°.

29.3 Calculating the properties of some common shapes

The area of a square or rectangle is calculated by multiplying its length by its width:

$$A(\text{square or rectangle})=l \times w$$

The distance around the outside of a shape is called the perimeter. The length of the perimeter is calculated by adding the length of all the sides together.

As a rectangle has two sets of sides of equal length the **perimeter of a rectangle** can be calculated by multiplying two times its length and adding to that two times its width:

$$P(\text{rectangle})=2l + 2w$$

As a square has four sides of equal length the perimeter of a square can be calculated by multiplying the length of any one side by four.

The area of a square or rectangle is calculated by multiplying its length, width:

$$A(\text{rectangle})=l \times w$$

The **area of a triangle** is half of the length of its base multiplied by its height:

$$A(\text{triangle})=(b \times h)/2$$

The **area of a parallelogram** is calculated by multiplying the length of its base by its height;

$$A(\text{parallelogram})=b \times h$$

The area of **trapeziums, kites and rhombuses** can be calculated by splitting the shapes into two triangles, finding the area of each, then adding the areas together

The **diameter of a circle** is the length of a straight line that passes through the circle's centre and terminates on the circle i.e. the width of the circle at its widest point.

The **radius of a circle** is half of its diameter.

The **area of a circle** is calculated by squaring its radius and multiplying it by Pi (π, approximately 3.14):

$$A(\text{circle})=\pi r^2$$

The **circumference (perimeter) of a circle** can be calculated by multiplying its radius by two times Pi (π, approximately 3.14) or by multiplying its diameter by Pi (π):

$$C=2\pi r$$

Or:

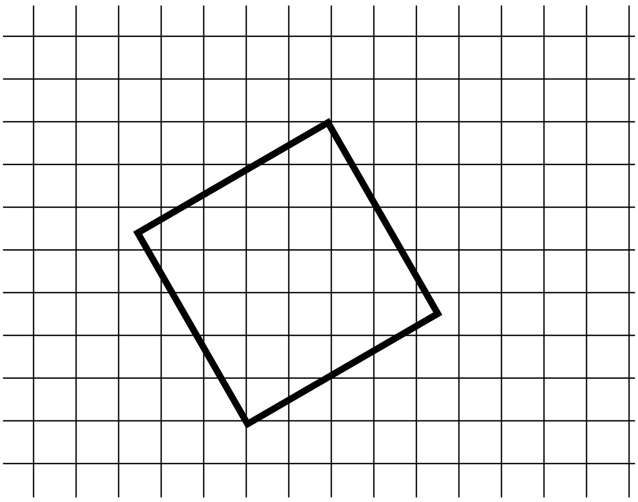
$$C=\pi d$$

29.4 Examples

Using the information given above, solve the following problems, showing your working where applicable.

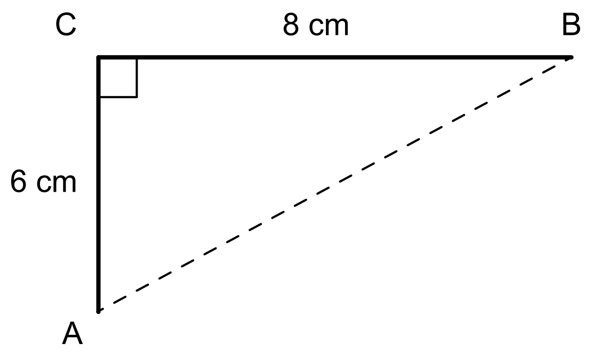
Activity

EXAMPLE 1: Find the area of this square if the grid lines are 10mm apart



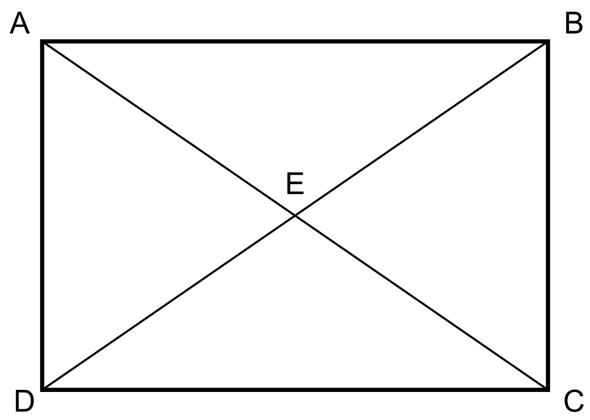
Activity

EXAMPLE 2: A surveyor is setting out a right angle. If AC = 6m and BC = 8m, what is the distance between A and B?



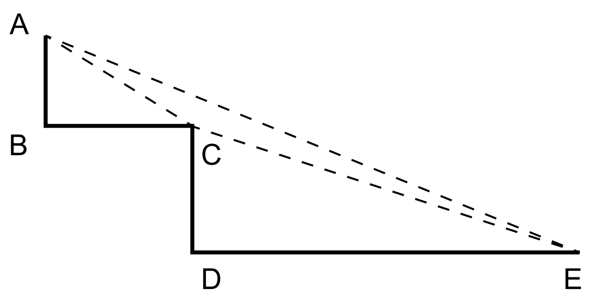
Activity

EXAMPLE 3: ABCD is a rectangle formed by scaffolding poles. The diagonal poles AC and BD keep rigid. They intersect at E.
AD = 2m and DC = 3.5m
What are lengths BD, AC and AE?



Activity

EXAMPLE 4: A surveyor is checking measurements for the foundation of a house to ensure that the walls are at right angles AB = 4m, BC = 5.1m, CD = 3.1m and DE = 8.5m What are lengths AC, CE and AE if the angles at B, C & D are true right angles?



Activity

EXAMPLE 5: Decide whether the following questions are about length, area or volume:

a) How far is it from London to Manchester?

b) How big is your garden?

c) How many tiles will I need to cover my bathroom floor?

d) How many books can I fit in this box?

e) How big a van do I need to move my furniture to a new house?

f) How much material do I need to make curtains for my kitchen windows?

Activity

EXAMPLE 6: What are the most common metric units for measuring:

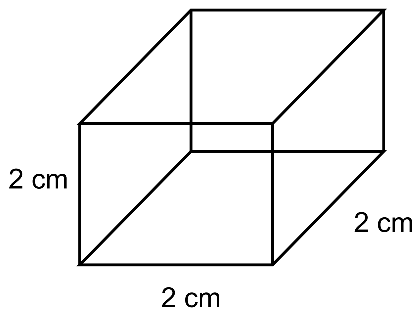
a) Length

b) Area

c) Volume

Activity

EXAMPLE 7: How many 20mm cubes could you fit on this sheet of paper:

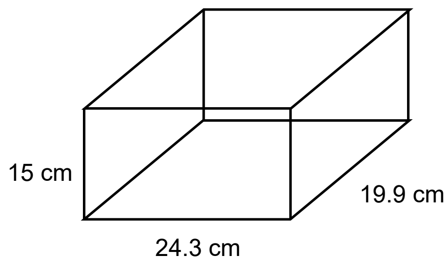


a) without going over the edge

b) so that no paper shows

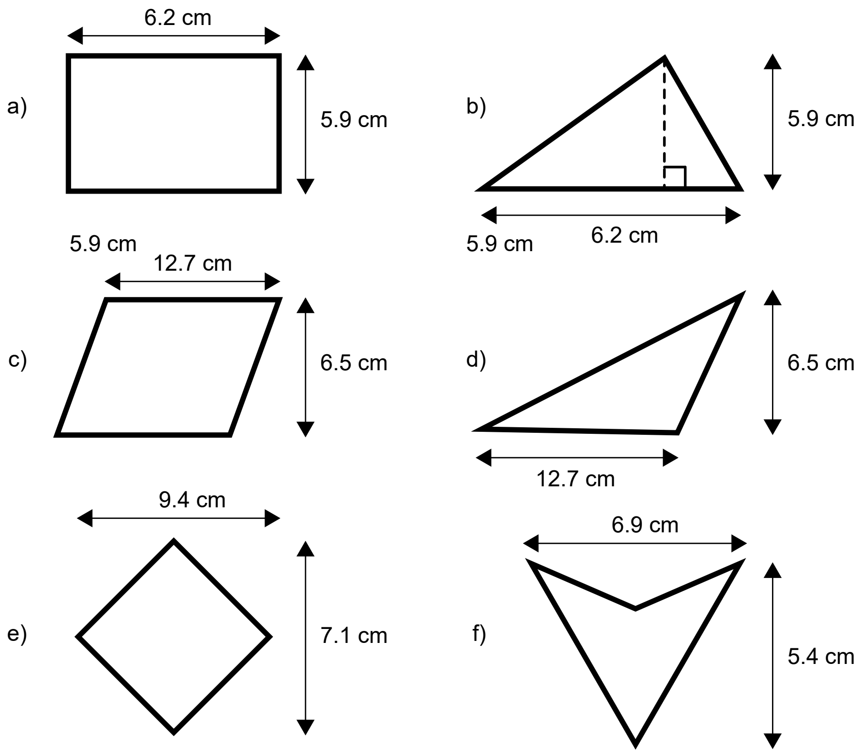
Activity

EXAMPLE 8: How many whole 20mm cubes could you fit inside a box with these measurements?



Activity

EXAMPLE 9: Calculate the areas of these shapes:



30. Supervision and management skills

30.1 Overview

To obtain the Gold Award you are required to prove to your Assessor that you have developed good team leadership skills and abilities.

This workbook doesn't aim to teach you these skills but acts as a guide to explain what you can do to achieve the required standard.

The most obvious way is for you to have studied for a supervisory/management qualification or certificate through a recognised body. You will most probably find several options locally to take this option and more than likely your local college will be able to help.

Alternatively, you could attend suitable courses organised by the professional institutes and other such organisations. NVQs or SVQs are also available in management.

The other way is that you will have picked up the necessary skills and experience on the job and can be relied upon to control and manage a team of designers to produce finished designs on time and within specification repeatedly.

The basic facts of leading and managing a team can be divided into three main areas:

- managing yourself
- managing people
- managing tasks.

Taking each in turn and breaking them down further shows you some of the areas you may need to concentrate on. These may not all come naturally to you, however where that is the case it is likely that you will improve and become more comfortable with continued effort and experience.

It may also be beneficial to mark yourself out of ten for each – please circle as appropriate.

30.2 Managing yourself

Responsibility: are you comfortable with responsibility and taking responsibility for your own actions?

1 2 3 4 5 6 7 8 9 10

Self confidence: are you confident in your own abilities?

1 2 3 4 5 6 7 8 9 10

Results oriented: can you deliver on set targets?

1 2 3 4 5 6 7 8 9 10

Active learning: do you continually want to better yourself?

1 2 3 4 5 6 7 8 9 10

Integrity: do you have good morals and honesty?

1 2 3 4 5 6 7 8 9 10

Toughness: do you deal well with difficult and challenging situations and face them head on?

1 2 3 4 5 6 7 8 9 10

Flexibility: can you change and adapt to situations quickly?

1 2 3 4 5 6 7 8 9 10

Personal organisation: do you think and act logically at home and at work?

1 2 3 4 5 6 7 8 9 10

Assertiveness: have you the strength to tell your workmates what to do?

1 2 3 4 5 6 7 8 9 10

Coaching: do you feel that you get the best out of everyone and that they improve under your leadership?

1 2 3 4 5 6 7 8 9 10

Team leadership: are you the leader and seen to be? Do your team and colleagues respect you?

1 2 3 4 5 6 7 8 9 10

30.3 Managing people

Influencing: do you lead by example and will people do what you say?

1 2 3 4 5 6 7 8 9 10

Managing change: will people do things differently if you ask them?

1 2 3 4 5 6 7 8 9 10

Listening: are you a good listener and do you take other peoples' ideas opinions on-board? You may have to ask others to answer this one!

1 2 3 4 5 6 7 8 9 10

Questioning: are you easily fobbed off and diverted or are you inquisitive and dig beneath the surface?

1 2 3 4 5 6 7 8 9 10

Interfacing: are you comfortable when other managers, designers and trades become involved?

1 2 3 4 5 6 7 8 9 10

Team working: have you developed a team or group of individuals?

1 2 3 4 5 6 7 8 9 10

Communication: does your team communicate well and are they up to date with what is happening?

1 2 3 4 5 6 7 8 9 10

30.4 Managing tasks

Analytical thinking: do you collect and consider the fine detail?

1 2 3 4 5 6 7 8 9 10

Creative thinking: do you regularly think of doing things differently?

1 2 3 4 5 6 7 8 9 10

Thinking conceptually: are your thoughts practical and workable?

1 2 3 4 5 6 7 8 9 10

Planning: they say a good plan accounts for 50% of the job. Does yours?

1 2 3 4 5 6 7 8 9 10

Organising: are your team supplied and equipped with what they need, and at the right time?

1 2 3 4 5 6 7 8 9 10

Controlling: are you in control of the work and resources around you?

1 2 3 4 5 6 7 8 9 10

Decision making: when necessary, do you make decisions quickly? Do you take responsibility for the consequences of making wrong decisions?

1 2 3 4 5 6 7 8 9 10

Quality orientation: do you demand high standards and maintain them?

1 2 3 4 5 6 7 8 9 10

30.5 Problem solving

Many of your tasks will be based around problem solving. The following process of how to go about finding solutions for problems may be beneficial.

Objective – what do you want to achieve?

What do you need to achieve this? e.g. resources, time, new skills

Have you done something similar before?

If Yes, what did you do? How did you do it?

If No, do you know anyone else who has tackled this type of issue or has the relevant skills and/or experience to help?

Identify options and possible actions:

What actions did you take?

What are the pros and cons of each?

Which of these options is likely to produce the most effective result in terms of, for example, client satisfaction, cost, staff motivation etc?

Having considered the options, what are you most attracted to doing?

What are the first things you will do?

What could happen to stop you?

How would you get around this?

What's the hardest part likely to be – how are you going to deal with this?

What support is required, and from whom?

Out of ten, how committed are you to achieving this?

Problem solved? If so, make a start...

31. Final review

Congratulations!

On behalf of the STA and CITB we hope you have enjoyed this workbook on Knowledge for Timber Frame Design.

As a reminder, we have included below a simple checklist for you in this final review. When arriving on site you should now know what key points to consider before you start work.

Here are a few we hope you will remember:

- general knowledge of timber from the forest to the wood
- general knowledge of timber frame
- benefits of timber frame
- knowledge from the soleplate to the roof
- knowledge of key areas such as fire resistance, acoustic performance, thermal performance, differential movement and vapour control
- an appreciation of engineering design, materials, components, floor, wall and roof structures and foundations
- an appreciation of multi-storey timber frame buildings
- specification of a timber frame kit.
- an appreciation of supervisory and management skills.

Most importantly, once you have been assessed on these Knowledge Workbook in combination with the Health and Safety and Practical Skills Workbooks, you will have reached the highest level of qualification available for timber frame design in the UK and a level which the industry wishes all timber frame designers will achieve over the next few years.

For most of us our home is our largest expense and we expect it to be built to the highest standards by well-trained and suitably qualified people. By using these Workbooks, we as an industry, can now provide you with the opportunity to achieve this goal. Also by having a qualified workforce we can compete with the rest in quality & workmanship.

Thank you for taking part in this training experience and we hope you will enjoy a successful and satisfying career in our timber frame industry. These workbooks have been prepared by the Structural Timber Association, in conjunction with CITB, on behalf of the industry.

STA and CITB operates a continuous improvement policy and would therefore be very grateful to receive any review comments for further editions.

Thank you.

Candidate and supervisor's final sign off

On completion of this workbook the named candidate and authorised supervisor are required to complete this final sign off declaration to confirm that:

- All aspects of the workbook have been successfully completed by the named candidate in accordance with the workbook and scheme requirements
- The named candidate has met the minimum experience requirements (1 year) in accordance with scheme requirements
- The named candidate is ready to register and undertake the online test.

CANDIDATE NAME	
COMPANY	
TEL No.	
EMAIL	

Candidate declaration

I can confirm that I have successfully completed this workbook in accordance with workbook and scheme requirements, have met the scheme minimum experience requirement of 1 year and am ready to register and undertake the online test.

CANDIDATE NAME ______________________

CANDIDATE SIGNATURE ______________________

DATE OF DECLARATION ______________________

SUPERVISOR NAME	
JOB TITLE	
COMPANY	
TEL No.	
EMAIL	

Authorised supervisor declaration

I can confirm that the named candidate has successfully completed this workbook in accordance with workbook and scheme requirements, has met the scheme minimum experience requirement of 1 year and is ready to register and undertake the online test.

SUPERVISOR NAME ______________________

SUPERVISOR SIGNATURE ______________________

DATE OF DECLARATION ______________________

NOTE: This workbook must be retained and presented for STA audit purposes upon request.

Structural Timber Association

Head Office

The e-Centre

Cooperage Way Business Village

Alloa

Clacks

FK10 3LP

Tel: 01259 272140

Fax: 01259 272141

Website:

www.structuraltimber.co.uk

CITB

Unit 1 and 2

674 Melton Road

Thurmaston

Leicester

LE4 8BB

Tel: 0300 456 5561

Fax: 0300 456 5562

Email:

enquiries@citb.co.uk

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Kingspan

John Meiling

Tsvetomila Duncheva

Authors

Dr. Tsvetomila Duncheva

Mark Milne

Prof. Robert Hairstans

Carola Calcagno (editorial)

Edinburgh Napier University

Project team members

Andrew Carpenter (STA)

Bob Davis (STA)

Tony Batchelor (BWF)

Paul Allford (CITB)

Martin Bruton (CITB)

Susan Hudson (SMTS)

TIMBER FRAME WORKBOOKS