STRUCTURAL TIMBER ASSOCIATION
Building solutions in timber

Edinburgh Napier UNIVERSITY

citb

TIMBER FRAME WORKBOOKS

Manufacturing

KNOWLEDGE

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1. Introduction and Welcome

1.1 The STA Design Training Programme

Welcome to your Knowledge Skills 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 competencies 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 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:

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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 solutions in timber

2. Aims and Objectives

2.1 Target audience

The Manufacturing workbook series is aimed at timber frame manufacturers, all staff who are involved in the manufacturing of timber frame components on the shop floor of a timber frame business.

The manufacturer should be based at a timber frame business for the practical part of their training.

The key responsibilities of the timber frame manufacturers are expected, to be, but not limited to, dealing with goods inwards, cutting of materials, assembling timber frame component on benches or using mechanised and automated manufacturing equipment, and quality inspecting and preparing the manufactured timber frame products for despatch.

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 know 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 manufacturer.

2.3 What is in this workbook

This workbook is divided in to 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, 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.

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 £7 billion 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.

3.2 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 will be debarked and passed through the sawmills
- **Treatment:** timber will usually be treated using a suitable preservative
- **Architecture:** an architect will

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%)

design the building or previous architectural designs will be used

- **Engineering:** the forces on the frame will be calculated, the arrangement and materials will be specified by an engineer
- **Timber frame design:** the architectural design will be passed to the timber frame business in-house fabrication designers manufacturer to design and produce the timber frame kit
- **Timber frame manufacture:** the manufacturers produce the elements as specified by the in-house fabrication designers
- **Marketing:** the timber frame manufacturers will be marketing their properties right across the spectrum to potential customers
- **Private and public sector house builders & housing associations:** are customers targeted by the timber frame companies
- **Construction companies:** these are customers and will be 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.

Activity

Give some examples of timber products

Activity

Find out the origin of the majority of the timber used at your company

3.3 Wood-based panels

Wood-Based Panels are manufactured composite products comprised 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.

3.3.1 Plywood

Plywood is flat panels made by bonding together, under pressure, a number of thin layers of veneer, often referred to a 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.

3.3.2 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 three layers, the strands in the external layer 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.

3.3.3 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.

3.3.4 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.

3.3.5 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 than 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.

Activity

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

3.4 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 recognised 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)

3.5 Wood markings and strength

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 in to strength classes which each have characteristic material properties which can be applied to all the species and grade combinations within the specific class.

3.5.1 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

Some examples of grading machines:

- MICROTEC GoldenEye-702
- Dynalyse Dynagrade
- Dynalyse Precigrader

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.

3.5.2 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

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.

Activity

What stamps should you look out for when examining timber at your factory?

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.

3.6 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 in to consideration during grading.

3.7 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 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, seen by others, sawn timber (rough sides) is commonly used under flooring or out of sight in the attic. Planning timber on all sides is not always convenient, that's why some sawmills offer planning timber only on the required sides.

3.8 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.

3.8.1 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.

3.8.2 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.

3.8.3 Water repellent (WR) treatment

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.

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.

3.9 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 felled after 30 years.
- Low density timber resulting in relatively low strength.
- Has to be treated 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 time taken the tree to mature.

4. Timber frame - the basics

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 encloses the timber frame to provide protection from the elements and aesthetics.

Typically, the inner and outer leaves 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 ten storeys. Timber frame is used to construct housing, apartments, hotels, schools, healthcare facilities, sports halls and other building types.

A qualified structural engineer certifies every timber frame project.

4.1 Useful facts you should know

Small panel 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

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

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.

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.

Off Site 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.

On the other hand, 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.

4.2 Main methods of timber frame 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.

4.2.1 Sub-assemblies

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

4.2.2 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.

4.2.3 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.

4.2.4 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. Less common and typically more expensive method

4.2.5 Post and beam/Stick built/Balloon frame

Components cut off-site and assembled on-site 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 post-and-beam type construction.

4.2.6 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 in to 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 on-site and increased quality as a result of fabrication 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

Activity

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

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.

4.3 Manufacturing systems

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

4.3.1 Open panel/

Conventional platform frame

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 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 internal linings are installed.

4.3.2 Pre-insulated (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.

Pre-insulated 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.

Pre-insulated 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 sole plate 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.

4.3.3 Floor and roof cassettes

similar in configuration to pre-insulated 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.

4.3.4 Structural insulated panels (SIPs)

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

Formed using a rigid 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 are very versatile and offer excellent thermal and structural performance due to the nature of construction.

4.4 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.

4.5 Building manufacture

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

4.5.1 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.

4.5.2 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.

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.

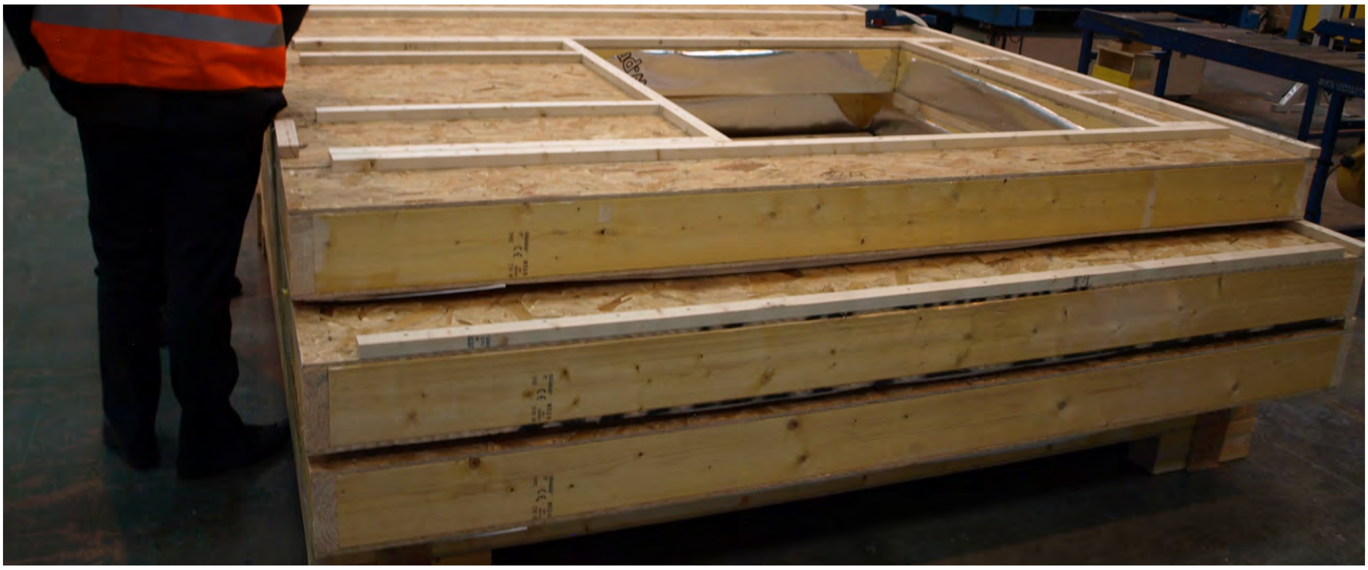
Activity

List and describe some of the CAD/CAM equipment which your company use.

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.

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.

5. The benefits of timber frame

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.

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.
- **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.

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

Activity

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

5.2 Processes – fabrication design, manufacture and erection

Some of the activities and operations commonly undertaken are 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.

- **Timber Frame 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 connectors
  - 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

soleplates

- Erection and management of scaffolding
- 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 someof the stages of the supply chain, from the forest to the completed structure

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

6. Manufacturing Production Line

6.1 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.

6.2 Factory layout and flow

The physical layout of the factory influences the way it operates 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 which in to 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 are to be erected on site and planning of the most practical and economical route.

Example value-adding activities:

- Machining
- Assembling

Example waste activities:

- Moving
- Storing
- Inspecting
- Scrapping
- Re-working
- Sorting

Activity

Sketch the layout and flow of your company's production facility (use separate blank sheet)

Activity

Carry out an audit of the factory layout using the instructions below (use separate blank sheet)

How to carry out a factory layout or process audit

1. List the steps taken in your manufacturing process in the order that they take place.

2. Draw your factory layout on an A3 sheet of paper (identify each machine and area).

3. Draw the steps taken in the manufacturing process flow on the sheet of paper

4. Measure the distance a product (and all the associated parts) travels in the process. You will be surprised at the total distance travelled.

5. Look for non-value added activities moving, storing, counting, inspecting, scrapping re-working and sorting. These are all adding cost but not adding value. They can be reduced or eliminated without affecting the process and eliminating them will reduce cost.

6. Examine the process flow to reduce the distance travelled.

7. Ask how long it normally takes to complete the manufacturing process. Then ask how long it would take in an emergency if it were 'walked through' the process.

8. For most frame manufacturers in the UK the residence time is about 24 hours (3 x 8 hours) and the 'walk through time' is about 2 hours - the process spends 22 hours (91.5% of the time) adding cost and only 2 hours (8.5% of the time) adding value. If the 'paper processing' time is added then the average UK numbers change to: adding cost for 78 hours (97.5% of the time) and adding value for 2 hours (2.5% of the time).

9. Look for the step in the process that has the largest backlog of work. Measure the throughput of that operation (pieces/hour, for example). The step with the largest backlog will usually be the bottleneck in the process and will determine the capacity of the whole system. With window manufacture look at the movement of the bottlenecks as the product mix changes.

10. They will move by the minute but some will stand out.

11. This works just as well for your paper processes as for your materials processes.

Before you through the method some do's and don'ts.

- Don't set out to simply fill the space available, the further apart your processes and machines the greater the manufacturing time.
- Don't think of layouts in terms of regimented lines and patterns.
- Don't formulate long-term layouts that accept low

Do benchmark yourself by setting some targets you want to achieve as a result of the layout changes.

productivity or poor machine performance.

- Do take into account H&S regulations including risk assessments.
- Do involve the people working in the factory, they know what goes on better than anyone else.
- Do ensure that you only incorporate equipment that you need, there is a place for everything and good housekeeping practises are incorporated.
- Do benchmark yourself by setting some targets you want to achieve as a result of the changes.

6.3 Producing timber frame units

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)

Activity

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

Activity

Can you state - HOW - each of the following is handled in your work.

1. Obtain and follow the correct job instructions and any relevant assembly procedure and quality specifications.

2. Position and align the components correctly.

3. Monitor and control the assembly operation and identify any faults / variations / problems that occur.

4. Report any problems that you cannot solve or are outside your permitted authority to the appropriate person.

5. Produce assembled product/s that comply with the specification and quality requirements.

6. Deal appropriately with finished assemblies and complete any necessary documentation accurately and legibly.

Activity

1. What personal protective equipment needs to be used during the assembly activities and where can it be obtained?

2. What tools and equipment are used for the assembly operation and how to check that they are in a safe and usable condition?

3. Why it is important to follow the specified assembly sequence and procedure at all times?

4. What methods can be used to minimise waste during the assembly operation?

5. How to monitor the quality of the assembly and identify any variations from the specification?

6. What fault, problems or variations can occur in the assembly operation?

7. What documentation may need to be completed, and why it is important to complete it accurately and legibly?

8. Who are the appropriate people and what are their responsibilities within your working area?

6.4 Production flowcharts

Flowcharts are often used to show in diagrammatic form the method for manufacturing in the factory. In flowcharts different symbols represents different types of activities. Colour coding may be used as an additional method to distinguish between activity types. It is important that you understand the flowcharts.

How to read flowcharts:

https://www.smartdraw.com/flowchart/flowchart-symbols.htm

Activity

Find and study the production flowcharts at your company in detail. It is suggested that you walk through the factory whilst studying the flowcharts to truly understand the sequence, the activities and their interdependencies (use a separate sheet)

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7. Drawing office interface and procedures

7.1 Overview

The staff in the drawing office produce all the manufacturing drawings. The drawing office work together with the client, the project architect and the project engineer to ensure that the manufacturing drawings are accurate and that the final product meets the client requirements and complies with the relevant building regulations.

You will read the drawings produced by the drawing office and be responsible for manufacturing the timber frame components as specified by the drawings.

7.2 Drawing office

It is the responsibility of the drawing office to:

- Programme factory orders
- Produce accurate, current and correct manufacturing and sole plate drawings
- Liaise with the timber frame engineer
- Provide all external and internal joinery sizes
- Carefully read the specification, and inform production as soon as possible of any non-stock or bespoke products and materials

The suite of information that you may receive from the drawing office includes:

- 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
  - Work schedule including delivery schedule
  - Any special instructions
- Check lists

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.

It is **important** to ensure that the specification and production drawings have been read thoroughly and understood prior to starting work.

7.3 Production drawings, cutting lists and loading lists

All production documents 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.

When working with production documents, 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 production drawings, cutting lists and 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 cutting list upon providing a signature and/or initials.

7.3.1 Production drawings

Typically, the timber frame drawings you will have to read and understand 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
- Cutting lists
- Loading lists

8. Joists

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.

8.1 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.

Activity

Describe what you think are the main purposes of joists?

8.2 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.

8.3 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 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.

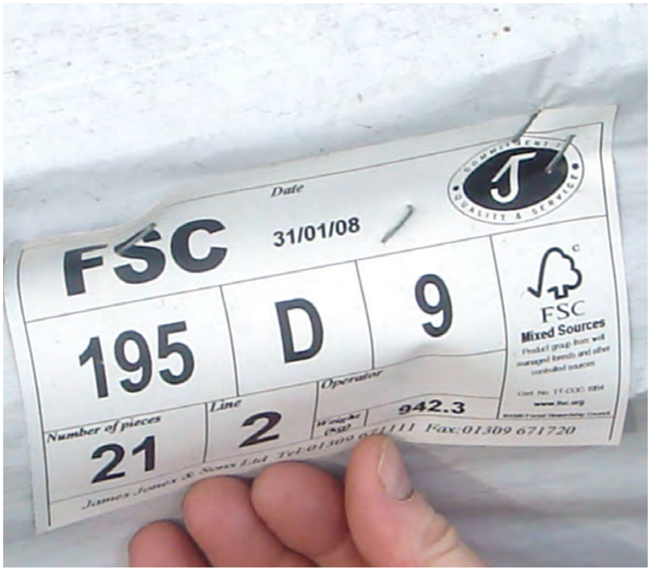
I-joists may be used as a core component of floor cassettes, wall panels and roof cassettes assembled offsite.

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

8.3.1 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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- 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.

8.3.2 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.

8.3.3 Cutting and holing I-joists

Holes can be made in I-joist webs to accommodate services such as electrical wiring, plumbing and ductwork. 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 be contacted for guidance if in any doubt.

8.3.4 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 be protected from weather prior to installation. Packs should be stored indoors where practical and covered at all times
- 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.

8.3.5 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.

Activity

What functions are I-joists used for in your factory?

8.4 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 in to 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 beams and I-joists share a number of advantages.

8.4.1 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.

8.4.2 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.

8.4.3 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.

8.4.4 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 be protected from weather prior to installation. Packs should be stored indoors where practical and covered at all times
- 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.

8.4.5 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.

Activity

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

Open web joist in showroom roof structure

Open web joist in factory shop floor

9. Quality Checks

9.1 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

Factory production control (FPC) provides documented, permanent and internal control of production which is robust.

- Standard procedures for correct handling of materials and assemblies
- Personnel training and competency records – roles and responsibilities.

9.2 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 con-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?

9.3 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 with the surface with none protruding or overdriven.
- **Cladding:** Checks are made to ensure that cladding is correctly positioned, oriented and installed.
- **Floor deck:** Checks are made to ensure that there 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 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.

Activity

What other assembly checks might be undertaken and why? Give specific examples relevant to a project in which you are involved?

9.4 STA Quality Certification Schemes

9.4.1 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 principle contractors /clients), to adopt the principles of Site Safe and register all sites they are involved with.

Further information:

http://www.structuraltimber.co.uk/members/why-use-an-sta-member/site-safe/

9.4.2 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.

Further information:

http://www.structuraltimber.co.uk

Activity

How does your company comply with STA accreditation schemes?

10. Multi-Storey Timber Frame Buildings

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

10.1 Factors to note

10.1.1 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.

10.1.2 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

10.1.3 Condensation

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

10.1.4 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.

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.

10.1.5 Differential movement

As the timber frame dries over the first two years of the building and as the loads of the building are applied, the timber shrinks and the overall height reduces resulting in differential movement between the timber frame and other parts of the structure. This can cause issues with the cladding material, if not controlled.

STA. Guidance. Differential Movement in Platform Timber Frame

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


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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 settlement.

Activity

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

10.2 Additional considerations

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.

10.3 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:

- Support structure / foundations
- Soleplates or bottom rails of panels where there are no soleplates
- Fixing down of soleplates or bottom rails of wall panels where there are no soleplates
- Walls
- Floors

10.4 Safety and construction procedures

As always, the regulations require that a risk assessment of the method of construction be 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.

10.5 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.

10.6 Important criteria for manufacturers

Four proven benefits for the multi storey construction market are:

- Supply
- Reduced Support Loads
- Quality
- Sustainability.

10.7 Examples

10.7.1 Timber Frame 2000 Project

In the year 2000 a timber frame building was constructed for the purpose of research into multi-storey construction of timber frame buildings. The project and its findings are outlined below.

Building overview:

- Six Storeys
- Four Flats / Storey, each with two bedrooms, kitchen, bathroom, living room and hall.
- Plan-aspect ratio of approximately 2:1
- Platform type Timber Frame
- Timber stair and lift shaft
- Single timber stair
- Brick cladding

The specifications were as follows:

- External Walls consisted of two layers of plasterboard with a vapour control layer and 89 x 38 mm C16 timber studs with mineral wool insulation in between. The sheathing is 9 mm OSB/3. The cavity is 60 mm with single leaf ½ brick cladding tied with stainless steel ties to timber frame.
- Internal load bearing walls consisted of C16 timber stud groups at 600mm centres with two layers of 12.5mm plasterboard and 9 mm OSB/3 sheathing to one side, where needed for wind bracing. The internal non-load bearing walls consist of C16 timber studs with one layer of 12.5mm plasterboard to each side. The compartment walls are twin-leaf using C16 timber studs with glass wool insulation in between and OSB Type 3 sheathing is used where wind resistance is required.
- The Compartment floors consist of two layers of plasterboard ceiling (19mm Plank 12.5mm plasterboard) on joists with mineral wool in between. OSB Type 3 is used as a floor deck. Floating floors contain proprietary resilient battens with plasterboard and Type P5 chipboard. Timber Joists with low moisture content of 12% were specified for floors 1 to 4 with the 5th. Comprising timber I-Beams and metal webbed beams.
- The roof comprises trussed rafters with hipped ends supporting concrete interlocking tiles on felt and battens.

Test programmes conducted were:

- Value engineering & process engineering.
- Differential movement.
- Whole building lateral (racking) stiffness.
- Disproportionate Collapse.
- Fire Compartmentation & Stairs.
- Acoustics.
- Guidance Documents.

Some of the findings of interest were:

- Cellular layouts are best suited to multi-storey platform timber frame.
- Internal load bearing walls may need to be strengthened to carry horizontal forces.
- Adding plasterboard lining to a sheathed timber frame building increased lateral stiffness by a factor of 3.3.
- Applying masonry cladding improved building stiffness by 17.7 times to that of bare timber frame sheathing.

Timber Frame construction for medium-rise buildings.

Further reading:
http://onlinelibrary.wiley.com/doi/10.1002/pse.2260010306/abstract

11. Fire Resistance

11.1 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

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.

11.2 General requirements

11.2.1 Products with enhanced fire resistance

There are varieties of non-combustible and limited combustibility products and 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 specifying the fire performance of such products must be verified by the manufacturer.

11.2.2 Compartmentation

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

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

11.2.2 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.

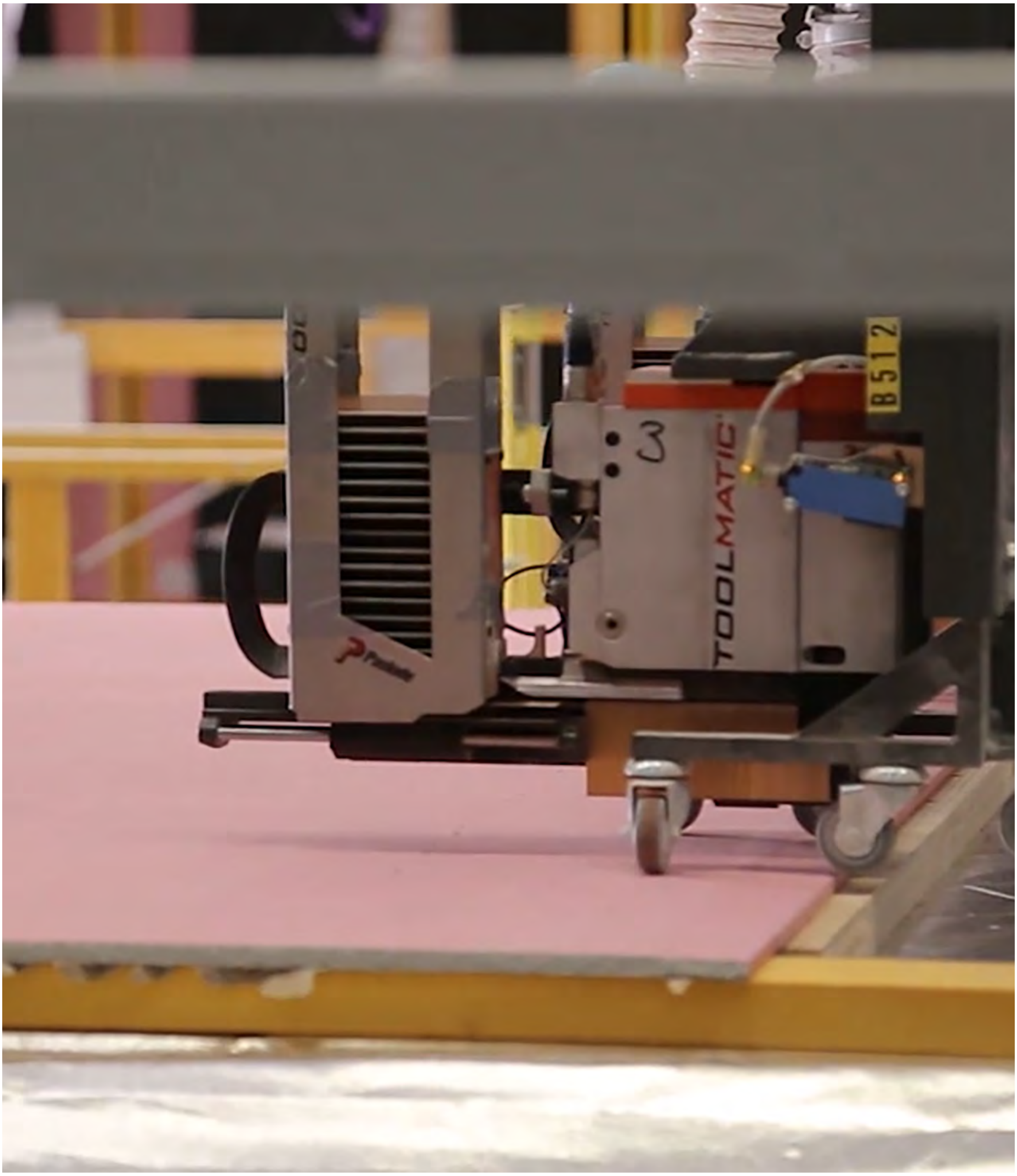
Cavity barriers must be installed such that they are adequately secured, bridge the full width of the cavity have no gaps. Cavity barriers should be lapped at joints and corners to ensure continuity is maintained.

11.3 Building regulations

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 depend on height and occupancy.

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



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

11.4 Walls and partitions

11.4.1 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 in to 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.

11.4.2 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

Activity

Find out the fire resistance duration requirements for the party walls and separating floors for a project in which you are currently involved elements, reducing centre to centre distances of elements, enhanced fixing details or fixing elements together to create multiple-ply elements, among others. Non-load-bearing walls separate areas of a building and neither carry nor transfer loads.

11.4.3 Internal walls

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.

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.

11.4.4 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.

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.

Service penetrations in party walls should be avoided or kept to a minimum. 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.

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 in to another part of the building which is under different occupation.

11.4.5 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). 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.

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.

11.4.6 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 in to 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.

11.5 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.

Floors may be constructed on site or pre-fabricated offsite as cassettes.

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.

11.5.1 Intermediate floors

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

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.

The joints in plasterboard linings must be taped and filled. Where 2 layers of plasterboard are used to provide enhanced fire resistance joints must be staggered.

11.5.2 Separating floors

Separating floors are those that separate different occupancies or purpose groups or which divide a large building in to a number of smaller compartments for the purpose of fire resistance.

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

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.

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.

11.6 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 in to 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.

12. Acoustics

12.1 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.

12.2 Building regulations

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.

12.3 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 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.

12.4 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.

12.5 Separating floors

Refer to the Robust Standards Details Handbook for information of all standard details for separating walls, 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).

12.6 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?

12.7 Sound transmission

12.7.1 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.

12.7.2 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.

12.7.3 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.

Activity

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

Increasing the overall depth of the separating floor is one way to enhance acoutstic performance.

13. 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 compression on the connections is also affected by differential movement. 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 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 in to consideration by designers and site personnel. As timber dries out, its cross-section shrinks and the structure settles.

13.1 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.

13.2 Locations most affected

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

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

- At locations where timber overhangs brickwork
- Flues and chimneys, including 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 in to account the shortening of the building).

The degree of differential movement may be more apparent in some locations than in others and increases as the building. Adequate provision for movement must be provided as appropriate.

13.3 Implications

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 upper 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.

13.4 Magnitude

Timber framed buildings reduce in overall height during the first two years of use. The magnitude of this movement is calculated by the timber frame designer. The following mechanisms, in order of magnitude, drive this characteristic:

- Reduction in the moisture content of the timber cross section (up to two years after hand over)
- Tightening up of joints under load (which is complete at the end of the construction period)
- Elastic shortening of compression members under load (which is a minor movement).

14. Thermal Insulation

14.1 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 buildings 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.

14.2 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.

14.3 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.

14.4 Mains factors for consideration

Target U-values for walls, floor, roof, windows and doors for each project

- Insulation type
- Number of insulation layers
- Thickness of insulation
- Insulation U-value
- Wall build-up U-value
- Insulation location within the structure – above/below the structure
- Cold bridging
- Air tightness layers
- MVHR (in very well insulated and air tightness buildings).

Activity

What are the standard insulation solutions used in your factory for walls, floors and roofs? Sketch details below, identifying type, thickness of insulation and cold-bridging solutions.

15. Moisture Control Layers

15.1 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.

15.2 General requirements and considerations

15.2.1 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.

15.2.2 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.

15.2.3 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.

15.2.4 Window and door openings

Membranes should be lapped in to openings, at the corners of openings and be adequately sealed as appropriate and in accordance with the manufacturer's instructions.

15.2.5 Party walls

Party walls should be treated as external walls and provide a continuous air barrier.

15.2.6 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.

15.2.7 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.

15.3 Location

15.3.1 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.

15.3.2 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.

15.3.3 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.

15.4 Installation

15.4.1 Vapour control layer

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.

15.4.2 Air barrier

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.

15.4.3 Breather membrane

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 considerations when installing:

A vapour control layer

Breather membrane

An air barrier

16. Typical Example of Timber Frame Kit

16.1 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.

16.2 Ground floor

16.2.1 Concrete slab and insulated ground floor

- Insulation
- Concrete slab
- Membranes
- Floor battens
- Floor deck
- Floor finish.

16.2.2 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.

Activity

Sketch below a typical ground floor detail used in your factory.

16.3 Upper floor

16.3.1 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.

16.3.2 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
- Resilient bar
- Ceiling lining.

Activity

Sketch below a typical upper floor detail used in your factory

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16.4 External walls

- Studs
- Rails
- Noggings
- Head binder
- Top and bottom rails for openings
- Sheathing (external/cavity)
- Insulation
- Lining (internal)
- Membranes
- Tie-down straps
- Wall ties
- Lintel
- Fire stops
- 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.

Activity

Sketch below a typical external wall detail used in your factory.

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.

Roof truss erection on site.

Wall panel erection on site.

Wall panel production in the factory.

16.5 Internal walls

There is typically little difference in the construction of load-bearing and non-load-bearing internal wall panels. 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 greater than 200mm. 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 enhanced acoustic performance. The cavity between the leaves may or may not be insulated.

16.5.1 Load-bearing internal wall panels

- Studs
- Rails
- Noggings
- Head binder
- Lintel (above door openings)
- Insulation
- Linings.

16.5.2 Non-load-bearing internal wall panels

- Studs
- Rails
- Noggings
- Head binder (for continuity)
- Insulation
- Linings.

16.5.3 Party walls

- Studs
- Rails
- Noggings
- Head binder
- Sheathing
- Insulation (between stud bays and in cavity)
- Cavity barriers (where specified)
- Netlon mesh
- Bracing
- Party wall straps.

Activity

Sketch below a typical party wall detail used in your factory.

16.6 Roof

16.6.1 Trussed rafter roof

- Fink trusses
- Noggings
- 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

16.6.2 Gable end

- Spandrel panel
- Gable ladder

16.6.3 Hip end

- Girder truss
- Hip trusses
- Hip rafters / boards
- Mono trusses
- Trim rafters

16.6.4 Valley

- Valley trusses
- Valley rafters/boards

16.6.5 Sundries

- Insulated ceiling hatch
- Meter board and hot water cylinder plinth

Activity

Sketch below a typical roof detail used in your factory.

16.7 Ironmongery / 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
- Angle brackets
- Framing anchors

Activity

List some of the connectors and straps which your company commonly uses.

- Wall ties – standard and high movement.

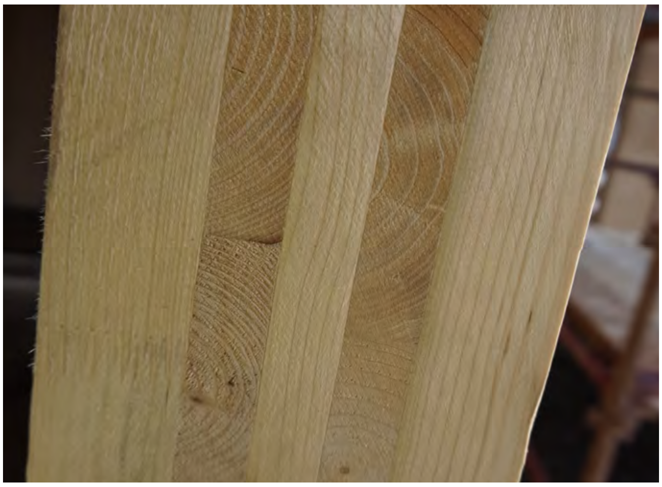
16.8 Sundries

- Weep vents
- Cavity trays
- Cavity barriers
- Lintels
- Loft access doors
- Flashings.

16.9 Structural timber

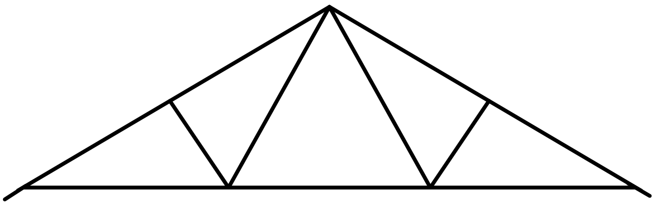
- Solid timber
- I-joists
- Open web joists
- Box beams
- Glued laminated timber (Glulam/GLT)
- Laminated Veneer Lumber (LVL)
- Parallel Strand Lumber (PSL) / Laminated Strand Lumber (LSL)
- Cross Laminated Timber (CLT) and variations of CLT:
- Nail Laminated Timber (NLT)
- Dowel Laminated Timber (DLT)
- 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.

Glue-Laminated Timber (Glulam)



Cross-Laminated Timber (CLT)

Laminated Veneer Lumber (LVL)



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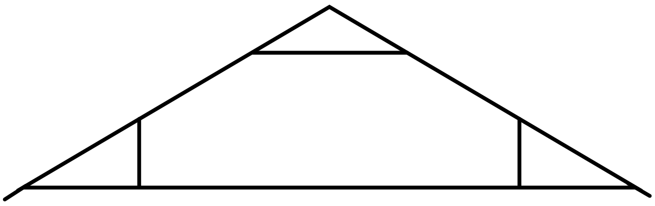

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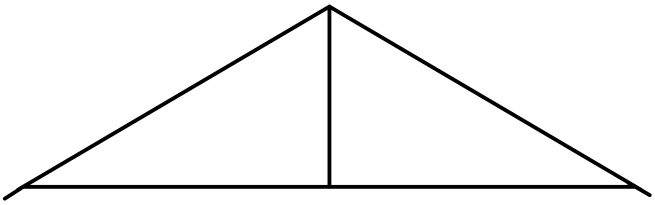
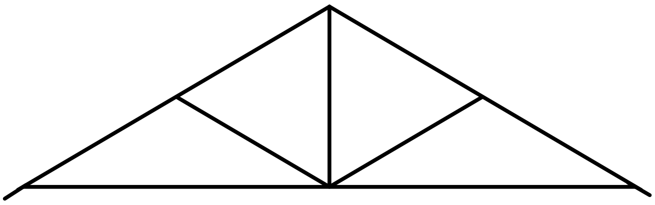
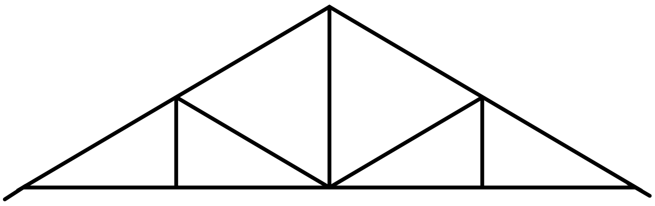


KING POST



QUEEN POST



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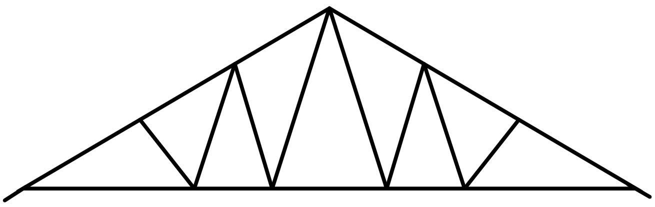


DOUBLE W

17. Maths

17.1 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.

17.2 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°.

17.3 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 by two times its width:

$$P(\text{rectangle})=2l \times 2w$$

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 volume of a square or rectangle is calculated by multiplying its length, width and height:

$$V(\text{rectangle})=l \times w \times h$$

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 in to 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** can be 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:

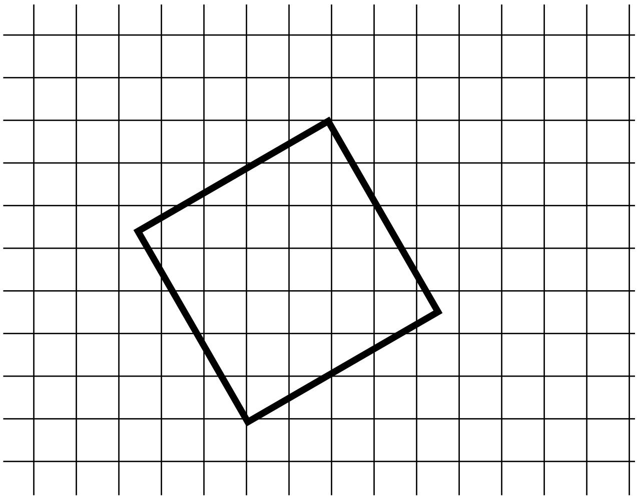
$$C = \pi d$$

17.4 Examples

Using the information given above, solve the following problems, showing your working where applicable.

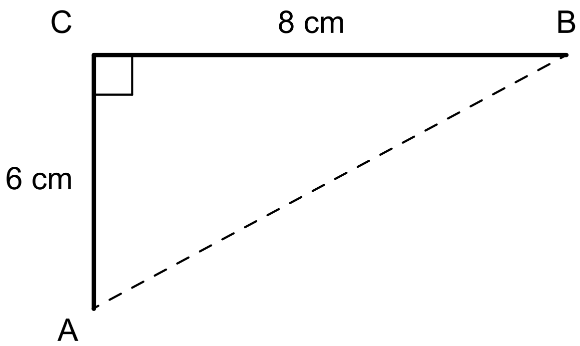
Activity

EXAMPLE 1: Find the area of this square if the grid lines are 10mm apart



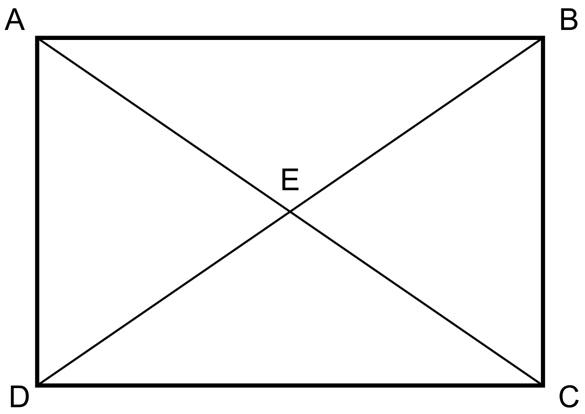
Activity

EXAMPLE 2: A surveyor is setting out a right angle. If AC = 6m and BC = 8m, what is the distance between A and B



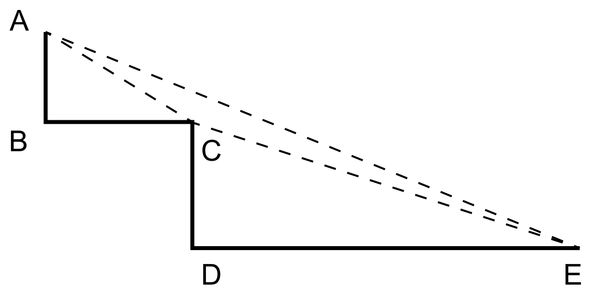
Activity

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:

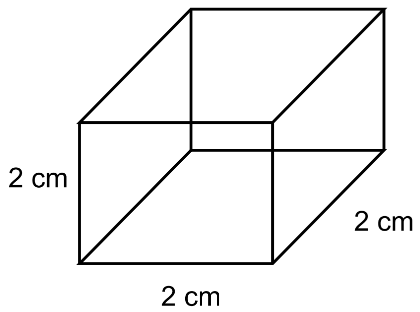
a) Length

b) Area

c) Volume

Activity

EXAMPLE 7: How many 20mm cubes could you fit on this sheet of paper:

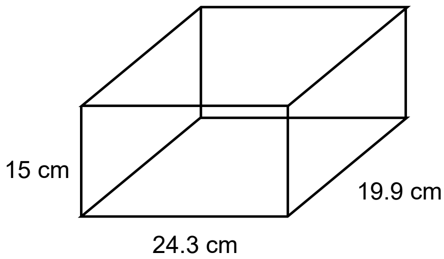


a) without going over the edge

b) so that no paper shows

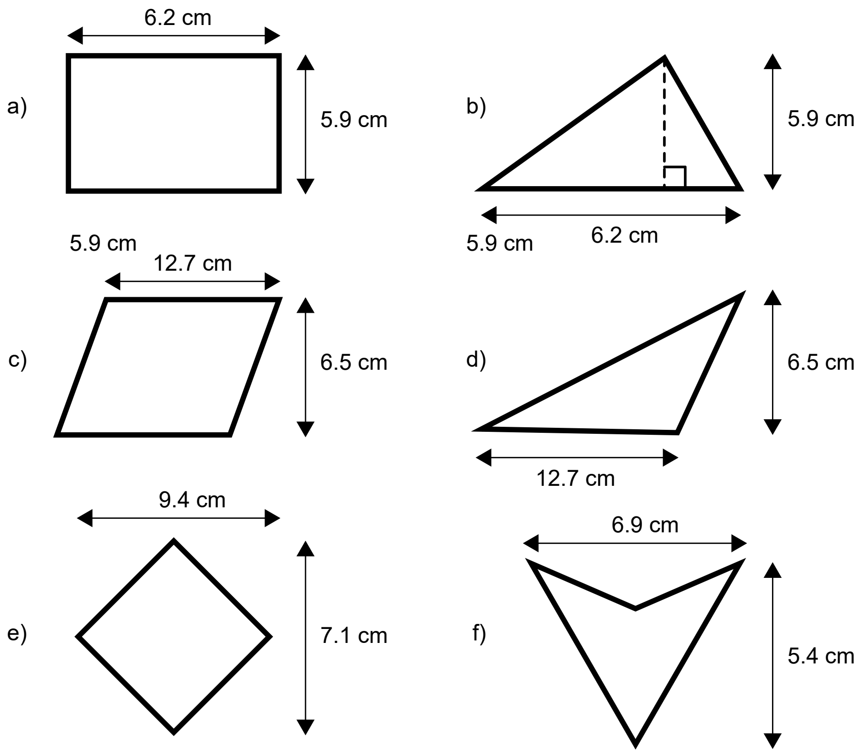
Activity

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:



18. 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 manufacturing process
- Knowledge of key areas such as fire resistance, acoustic performance, thermal performance, differential movement and vapour control
- An appreciation of multi-storey timber frame buildings
- Specification of a timber frame kit.

Most importantly, once you have been assessed on these Knowledge in combination with the Health and Safety Skills 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.

We hope that you will feel sufficiently pleased with your training experience to encourage other colleagues to use this training and to continue their own personal development.

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.

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