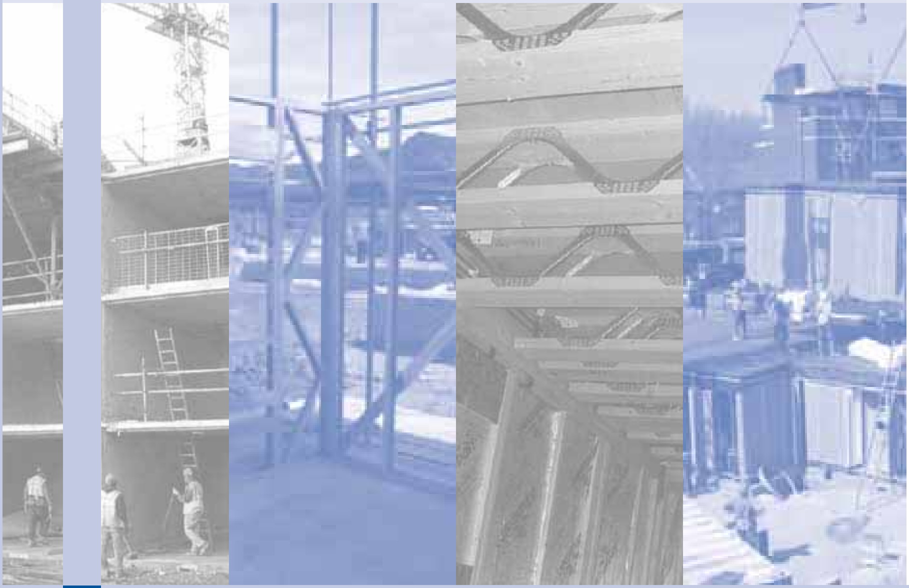
A guide to modern methods of construction

NHBC Foundation

Housing research & development in partnership with BRE Trust



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December 2006

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PREFACE

The NHBC Foundation has been established to help the house building industry to develop innovative and sustainable ways of meeting the demands for new housing. Its mission is to help set and improve the standard of new homes across the UK.

This guide is one element of a series that is expected to grow into a valuable resource for everyone in the housing industry – from regulators, lenders and insurers, through to designers, planners and builders, and on to clients and owners.

The aim of the series, in association with our other initiatives, is to add to the knowledge base of the industry and to provide clear, easy to access, information to assist the industry in meeting the challenges that it faces in these times of rapid change. To this end we will be developing further projects with our partners to further our aims and objectives.

Rod MacEachrane
Director, NHBC Foundation

December 2006

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We would like to express our sincere thanks to the following companies for supplying photographs for this guide:

Page number	Figure	Company
7	Closed timber frame panels being placed	Space4 Ltd
7	Concrete panels complete with insulation and half brick cladding	Milbank Danilith
9	Volumetric unit designed for use in a hybrid system	Advance Housing Ltd
10	Pre-fabricated foundation system	Van Elle Ltd
10	Steel framed floor cassette being lowered into place	The Forge Company
10	Roof cassettes being installed	Milbank Roofs Ltd
12	Concrete being poured into insulating formwork	Formworks UK Ltd

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INTRODUCTION

This guide is a concise reference tool that combines the experiences of architects, main contractors, engineers, warranty providers, manufacturers, and BRE who have applied modern methods of construction (MMC) successfully throughout the construction process. It provides guidance throughout all stages of a project from the development of the outline brief through to delivery on-site.

Although following the advice in this guide is not the only way to achieve a successful project, you will find valuable guidance here on most situations and commonly encountered problems.

Drivers for building with modern methods of construction

Shortage in housing supply

The rate of housing supply in areas of the UK, such as the South East where considerable growth is forecast, is lower than Government would prefer. High demand for housing in these areas is pushing up prices, making it more difficult for key workers and those on low incomes to find suitable accommodation. The development of affordable private sector dwellings is outside the control of Government so the focus has been on stimulating the development of MMC capacity as a means of increasing the rate of housing supply.

The Government has approached this aim by specifying that a proportion of dwellings procured using public funds, or on Government-owned land, will have to be constructed using innovative techniques. In practice this means that a proportion of dwellings built with Housing Corporation grants, or on land owned by English Partnerships, will be built using MMC.

Skills shortage

Under investment in training in the building industry in recent years has led to overall skill levels decreasing with potential implications for quality. The situation has been made worse by the greater use of contract, as opposed to direct, labour. Procurement is often on the basis of lowest tender/fixed price meaning there is little incentive for contractors to do more than the minimum required. It is also difficult for main contractors to predict the calibre of operative used on a job.

Recent moves towards partnering and best value approaches may be improving the situation, but those approaches are far from universal. In areas of high construction activity the lack of sufficient skilled labour is more acute. Most MMC housing is constructed wholly or in part in factories. Since the workforce in factories tends to be direct labour there is a greater incentive for the employer to invest in training, both for factory based operatives and site erection teams provided by the manufacturer.

Concerns about housing quality

It is difficult to draw firm conclusions about whether construction quality is getting better or worse. There is a perception that build quality is declining, but that is probably due more to high profile media coverage of a few examples of poor practice and increasing customer expectations, than to an overall decline. Conventional construction can, and in most cases does, provide good quality housing but there is a general feeling that quality will need to improve if only to meet the higher performance standards needed to comply with the revised Building Regulations (see below). There is a limit to what can be achieved in terms of predictable performance given the adverse working conditions on building sites and a largely contracted workforce. However, MMC housing manufactured in controlled conditions with a dedicated workforce has the potential to provide more consistent quality.

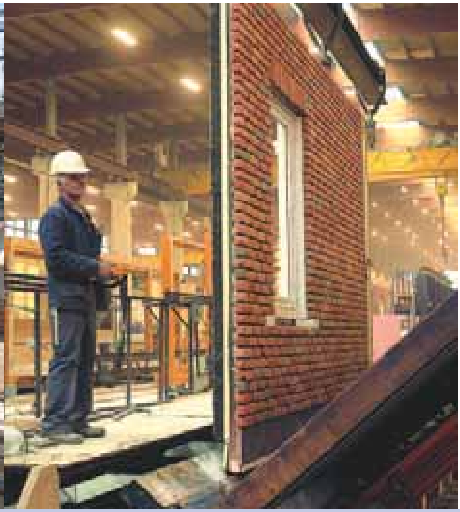
Revisions to Building Regulations

When the Building Regulations were introduced, they were concerned only with the health and safety of people in and around buildings. More recently the Regulations have been broadened to cover the performance of buildings, particularly their thermal and acoustic performance. In these cases house builders are not only concerned with meeting higher standards, but with the prospect that performance might be tested after construction: this can lead to costly remedial work if performance falls short of the standard required. Some house builders are looking at MMC as a potential way of providing more predictable performance in the completed dwelling.

Environmental performance

Increasing emphasis is being placed on the environmental performance of buildings, not only in use but also during construction, and the environmental credentials of the materials being used. One aspect of the construction process that is criticised on conventional sites is the level of wasted material, either through damage or profligacy. On conventional sites, materials are normally purchased in bulk and contractors are hired to fit them. There is little incentive for the contractor (who is usually on a fixed-price contract) to economise on the use of materials. With MMC, suppliers usually quote a price for manufacture or supply that includes the cost of the materials, so there is a much greater incentive for them to minimise wastage.

There are other environmental benefits particularly for manufactured dwellings because much of the work is conducted in a factory; therefore the impact on the local community in terms of noise, dust and traffic movements associated with conventional construction sites is reduced.

WHAT ARE MODERN METHODS OF CONSTRUCTION?

Modern methods of construction is a collective term used to describe a number of construction methods. The methods being introduced into UK house building differ significantly from so-called conventional construction methods such as brick and block. There is a great deal of debate within the industry at present about what constitutes MMC and as a result there is no universally agreed definition. In 2003 the Housing Corporation published a construction classification system (Box 1) that is used for its own purposes, which has been adapted by others.

BOX 1

Housing Corporation construction classification system for dwellings

1. Off-site manufactured – Volumetric
2. Off-site manufactured – Panellised
3. Off-site manufactured – Hybrid
4. Off-site manufactured – Sub-assemblies and components
5. Non off-site manufactured modern methods of construction

While it is recognised that a definition based on attributes such as efficiency and quality may be more logical, the fact remains that most MMC being constructed at present is subject to Housing Corporation grants, or is on English Partnership sites: in both cases their selection criteria use the Housing Corporation classification system. The information in this guide is therefore based on that system.

There are many other terms used in the context of MMC (see Box 2) but, in order to prevent confusion, they are not used in this guide.

BOX 2

Other terms used to describe MMC

- Factory built/assembled
- Industrialised construction
- Innovative systems constructed on-site
- Off-site assembly
- Off-site construction
- Off-site manufacture
- Modular construction
- Pre-fabricated construction
- System building

Volumetric construction

Three-dimensional units produced in a factory, fully fitted out before being transported to site and stacked onto prepared foundations to form the dwellings

Volumetric construction is also referred to as modular construction. These units can be made from most materials including light gauge steel frame, timber frame, concrete and composites. The units are sometimes used alongside panels (ready made walls, floors and roofs) in hybrid construction (see page 9).

'Pods' are another type of volumetric unit usually used for bathrooms or similar highly serviced areas. Pods are discussed on page 6.

Volumetric construction is most efficient when used for large numbers of identical units, as may be found in flats. A house is typically made up of four units plus roof (which can be either pre-fabricated or conventional). A flat usually comprises one, or more commonly two units.

TOP TIPS

1. Consult the manufacturer early in the development of the design – designing with the manufacturing process in mind can lead to manufacturing efficiencies.
2. Due to the size and weight of a volumetric unit, early consideration of transportation and erection logistics is necessary. Storage of the units on-site before erection is not recommended or practical.
3. Accurate foundations (eg ±5 mm on flatness) are essential due to tight tolerances of the units. Connections between units must also be carefully considered.
4. Design freeze (particularly of services) is essential before manufacture begins – any late design changes will be costly.
5. Ensure units are inspected both in the factory and on-site.
6. Consider the building control process. If the factory is remote from the site, one building control authority may undertake inspections in the factory, and another on-site.

Factory producing volumetric units

Volumetric unit as delivered to site showing level of internal fit out

Volumetric unit being placed on levelled substructure

Flats being constructed with volumetric units – all the units shown were placed in one day

Completed block of flats in volumetric construction

Volumetric construction: bathroom and kitchen pods

Factory finished bathrooms and kitchens within an independent structure

Pods were introduced into the construction market for hotels and student accommodation, although their use in apartments and housing is increasing. Pods are usually non-structural and are normally used within a loadbearing structure. The enclosure can be of steel frame, timber frame, concrete or composite constructions.

TOP TIPS

1. Most pods have to be sunk into the floor by about 50 mm to give a level floor finish – ensure the floor construction takes account of this.
2. Pods can be used to house other services such as heating equipment; consider this within the design.
3. Substantial repetition is required to ensure pods are cost competitive with conventional methods. Left and right-handed versions of the same design constitute two different types of pod.
4. Early design freeze and agreement on specifications are required.
5. Consider the sequence of works around the pod area, which may need to be carried out in advance of normal timescales.
6. If pods are installed while the rest of the structure is being built, it is important to protect them from the weather. Pods can also be a target for vandals if site security is poor.
7. If pods are to be delivered with doors rather than ply barrier, ensure that matching doors and furniture are available for the rest of the dwelling.
8. Pod designers should ensure access to services for maintenance, either within the pod or in the adjacent construction.

Stages in the construction of bathroom pods (a–c)

Pod being placed within a structure

Completed pods awaiting despatch from factory

Panellised construction systems

Flat panel units built in a factory and transported to site for assembly into a three-dimensional structure or to fit within an existing structure

Systems can include wall, floor and roof panels to create the complete structural shell. Factory-made structural floor and roof panels are known as 'cassettes' (these are considered in the sub-assemblies category on page 10).

There are many different types of panel, the main types are:

Open panels: panels delivered to site where insulation, windows, services and linings are fitted. All structural components are visible. Panels can be structural (transmitting load to the foundations) or non-structural (used as non-loadbearing separating walls and partitions).

Closed panels: panels based on a structural framing system (such as the type used for open panel systems), which can have factory fitted windows, doors, services, internal wall finishes and external cladding. The internal structural components can only be seen around the perimeter of the panel.

Concrete panels: structural wall panels, which can include cladding (often bricks or brick slips), insulation materials, windows and doors.

Composite panels: panels made from a combination of different materials that act together to provide structural support. Structural insulated panels are a specific form of composite panel.

Structural insulated panels (SIPS): sandwich construction comprising two layers of sheet material bonded to a foam insulation core. They do not rely on internal studs for their structural performance. Used primarily as wall and roof panels.

Infill panels: non-loadbearing panels inserted within a structural frame. Any type of panel can be used although framed panels are more common. Masonry can also be used.

Curtain walling: vertical building enclosure system that supports no loads other than its own weight and the environmental loads that act upon it.

Composite panels being used to construct a block of flats

Open steel frame panels

Closed timber frame panels being placed

Concrete panels complete with insulation and half brick cladding

TOP TIPS

1. Avoid steps and staggers with framed systems if using a heavy cladding such as brickwork. With conventional construction, brickwork between the roof of one dwelling and the verge of the adjacent dwelling is built off the party wall. With framed construction, brickwork cannot be supported on the frame of the party wall making detailing of the cladding difficult (see Figure 1). An alternative approach is to use lightweight cladding systems.
2. Consider the integration of panels with site-applied cladding and services.
3. Panellised construction is more cost effective than volumetric construction for projects with a variety of layouts.
4. Use experienced or specialist erection teams.
5. Manufacturers need an early design freeze, especially for services.
6. Tolerances are critical, particularly with infill panels.
7. Ensure the weight of each panel is known to ensure a crane of adequate capacity is provided (particularly for panels made from heavy materials such as concrete).

SIP panel showing construction

Light gauge steel infill panels

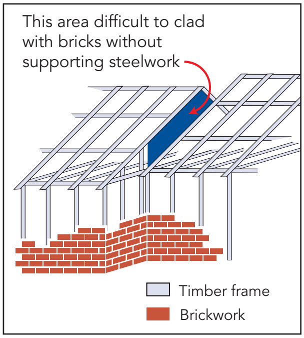


Figure 1 Steps and staggers can lead to difficulties with cladding

Hybrid construction

Volumetric units integrated with panellised systems

Hybrid construction is also referred to as semi-volumetric construction. Highly serviced areas such as kitchens or bathrooms can be constructed as volumetric units, with the rest of the dwelling constructed with panels.

TOP TIPS

1. If different materials are used for the volumetric and panellised units, care is needed in the design detailing.
2. Ensure detailed design has been carefully considered at the interface between the volumetric unit and panellised system. This is especially important if different manufacturers' products are being used.
3. Hybrid construction combines the best elements of volumetric and panellised construction. High value-added materials and fittings can be factory fitted into the volumetric units in controlled conditions, and panellised construction increases flexibility of layout.
4. Establish effective communication early between the manufacturer(s) and the project architect to optimise the design for the manufacturing process.

Volumetric unit designed for use in a hybrid system

Volumetric unit being placed alongside panels

Sub-assemblies and components

Larger components that can be incorporated into either conventionally built or MMC dwellings

These items are not full housing 'systems' and are usually factory made or, occasionally, site-assembled.

Sub-assemblies and components in this category are:

Pre-fabricated foundations: a series of pre-fabricated ground beams and other components assembled to form foundations quickly and accurately.

Floor cassettes: pre-fabricated panels specifically designed for floor construction. Fewer labour hours on-site are needed per square metre of floor, and reduced work at height has potential health and safety benefits.

Roof cassettes: pre-fabricated panels designed specifically for pitched roofs. The panels are very stiff and are designed to leave the loft free of struts and props, allowing easy production of 'room in the roof' construction. Using roof cassettes allows the building to become watertight more quickly than with conventional trussed rafter or cut roof constructions.

Pre-assembled roof structure: roofs assembled at ground level before constructing the shell of a dwelling. The roof can be craned into place as soon as the rest of the superstructure is in place, creating a weathertight structure more quickly than assembling the roof in situ. There are also health and safety benefits resulting from the workforce not undertaking all the work at height.

Pre-fabricated dormers: factory made dormers can speed up the process of making the roof watertight.

Pre-fabricated chimney stacks: factory made lightweight chimney stacks (often clad with brick slips) for mounting on a roof structure without the need for a masonry flue, make them suitable for lightweight frame constructions. The stacks can accommodate flue liners and so function with combustion appliances.

Wiring looms: cabling systems manufactured so that they can be assembled quickly with relatively unskilled labour. Cables are manufactured in various lengths and terminated with plugs that simply plug into sockets and other electrical items.

Pre-fabricated foundation system

Steel framed floor cassette being lowered into place

Roof cassettes being installed

Pre-assembled roof structure being lifted into place

Pre-fabricated dormers

Pre-fabricated plumbing: pipework and fittings pre-assembled for use in volumetric units to facilitate the rapid throughput of units in the factory.

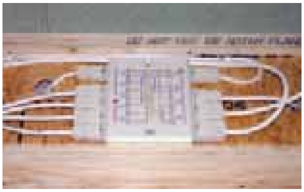
Timber I beams: lightweight joists, studs or rafters manufactured with solid or composite timber flanges with timber sheet material web to form an I beam. The beams are very stiff for their weight and manufactured in a range of lengths and depths. The beams can be used to create structures with large unsupported spans giving flexibility in layout.

Metal web joists: lightweight joists comprising two timber flanges separated by light gauge steel lattice webs. As with timber I beams, large spans are possible.

TOP TIPS

1. Ensure that the use of a sub-assembly adds value overall.
2. Ensure interface between the sub-assembly or component, and the rest of the structure, has been fully considered from the design stage onwards.
3. Be aware that the use of sub-assemblies can increase crane reliance.
4. Consider assembling roofs at ground level to reduce work at height.
5. Ensure preceding and follow on trades are fully briefed to understand and take advantage of MMC.

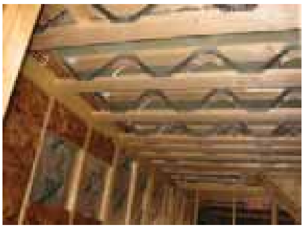
Pre-fabricated chimney stacks



Pre-fabricated cabling system

Pre-assembled plumbing

I beam timber joists



Metal web joists

Site-based modern methods of construction

Innovative methods of construction used on-site and the use of conventional components in an innovative way

A variety of systems are available which include:

Tunnelform in situ concrete: concrete bays cast between 'L'-shaped steel shutters (see Figures 2 to 4). The ends of the bays are infilled with other materials (eg masonry, light gauge steel or timber frame panels) to create a habitable space.

Insulating formwork: insulation in the form of hollow blocks or sheets used as permanent shuttering for concrete to create the external walls of a dwelling. Very airtight and thermally efficient dwellings are created using this system.

Aircrete: aerated concrete products (thin joint blockwork or aircrete planks) used to form the major elements (ie walls, roof and floors) of a structure.

TOP TIPS

1. Tunnelform is normally more efficient when used for large numbers of repeat units.
2. Tunnelform works well with other off-site manufactured systems (eg tunnelform and framed infill panel systems).
3. Ensure site has enough space for movement of (potentially) large components.
4. Aircrete uses conventional skills and is suited to both low and high output volumes.
5. Insulating formwork does not require heavy lifting equipment. Craft skills are not essential – very popular with self-build projects.

Figure 2 Tunnelform construction

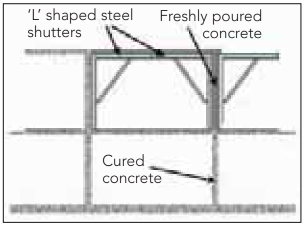


Figure 3 Tunnelform principle

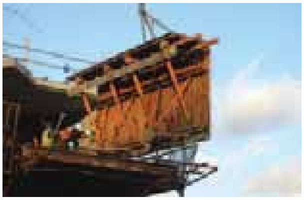


Figure 4 Steel shutter being removed from tunnelform after casting a bay

Concrete being poured into insulating formwork

Aircrete planks used to create a roof deck

Aircrete products used for the whole structural envelope

HOW MODERN METHODS OF CONSTRUCTION FIT INTO THE CONSTRUCTION PROCESS

Procurement and construction of conventionally constructed dwellings is by necessity a sequential process, which is represented in its simplest form in Figure 5.

Develop concept design	Pre-construction phase
Obtain approvals	
Develop detailed design	
Construct infrastructure	Project goes on-site
Construct substructure	
Erect superstructure	
Erect roof	
Fit out units	

Figure 5 The construction process

Figure 5 shows that only the design and approvals stages occur before going on-site. With site-based MMC, systems must follow a similar process but as the amount of work carried out in a factory increases, more flexibility is built into the process. Superstructure and fitting out can take place in the factory before or while the groundworks and substructure are being done on-site. This has the overall effect of compressing the on-site phase.

Figure 6 (overleaf) shows a comparison between various forms of construction during each stage of the construction process. As production in the factory increases the overall time on-site should decrease. However, the amount of work required before construction intensifies so the pre-construction phase becomes increasingly important. The key steps in the pre-construction phase are given in the next section.

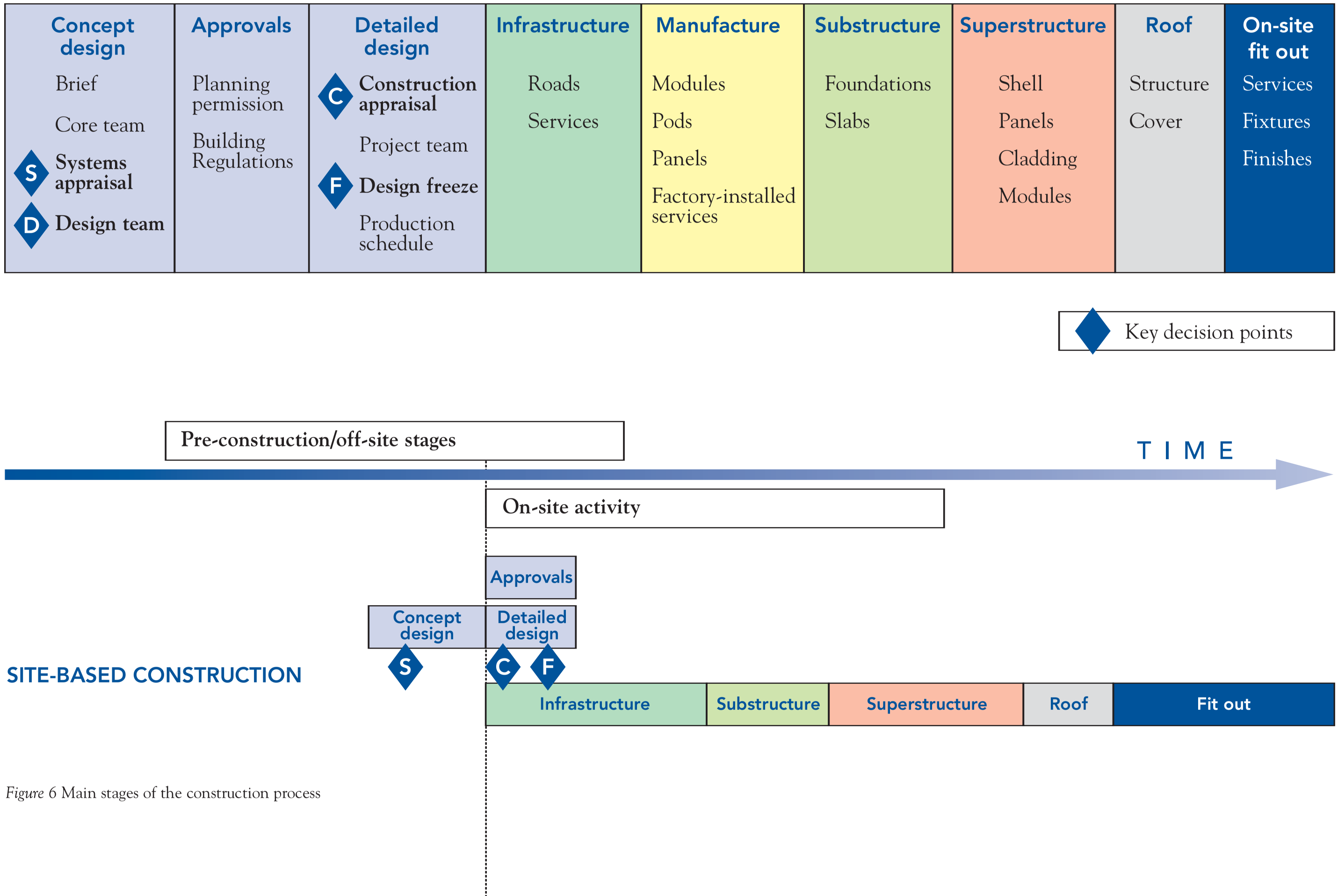


Figure 6 Main stages of the construction process

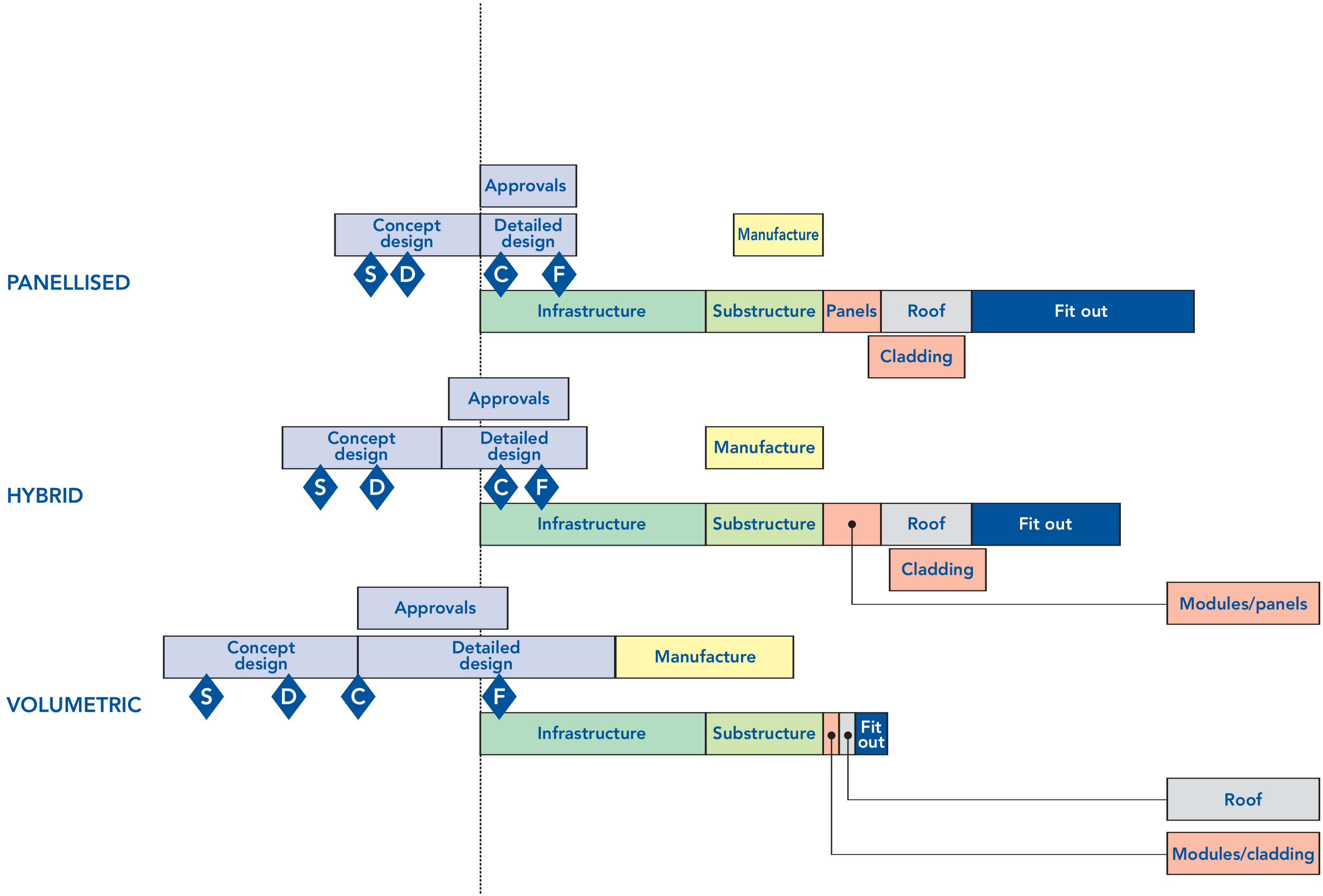


Figure 6 Main stages of the construction process (contd)

THE PRE-CONSTRUCTION PROCESS

The approach to constructing with MMC differs markedly between private sector house builders and housing associations. Private sector builders normally use standard house types from a pattern book. Experience has shown that converting a design intended for masonry construction to factory production is not easy, so if mainstream builders are to embrace MMC it usually involves careful and lengthy planning.

The usual approach is to form a strategic partnership with an MMC supplier in order to develop designs specifically suited for production. Often, the intention is not to completely switch to MMC, but to use it as a means of introducing flexibility into the supply of housing. However, such partnerships will only be entered into if there is a sound business case to support the decision.

Another factor as far as private sector/speculative house builders are concerned is the need to manage cashflow, which is directly related to both the build rate and the sales rate. Therefore forms of MMC which benefit from the economies of scale obtained from production runs of a number of dwellings (such as volumetric construction) may not be particularly suited to the private sector builder's business constraints.

Housing associations normally build to different standards (eg space and robustness) compared to speculative builders, and rarely use pattern book designs. While it is beneficial for them to earn revenue from rental income as soon as possible they do not tend to operate under the same business constraints as private sector builders, and generally want their housing finished as early as possible. The use of MMC is therefore more suited to housing association requirements than it is to those of the private sector.

Private sector builders

For private sector builders there are two possible, but independent, stages that may involve MMC. The first relates to the development of a strategic partnership with a manufacturer for the supply of MMC components or systems. The second relates to specific individual developments.

Developing a strategic partnership

Strategic partnerships between builders and MMC suppliers can be on a number of levels, depending on the extent to which the MMC product represents a complete dwelling. At one extreme the MMC supplier may be only a preferred supplier of a product, eg roof cassettes, while at the other extreme the MMC supplier could supply the whole dwelling. In the more extreme cases, complete house designs may need to be developed to enable the most cost-effective solution to be built on-site. In order to maximise flexibility from the house builder's perspective, the standard designs developed with the MMC supplier may share a common foundation design with the builder's conventionally constructed pattern book housing. This gives the house builder the flexibility of two approaches on the same plot.

Alternatively, the builder may feel that a particular dwelling type (eg flats) is more suited to MMC. Unlike detached or semi-detached houses, flats are not normally occupied until the whole block is completed, meaning that rapid construction techniques would allow sales to proceed more quickly.

Site-specific considerations

Developing a particular site begins with the identification and purchase of a plot of land. The purchase may be speculative, with considerable time lapsing between purchase and the start of the design and construction phases, but the decision to start the development process is taken on the basis of a business plan. Unlike the social housing sector, the business plan is reviewed regularly and the plans for the site altered to ensure that the development remains in line with market demand.

Different departments within a construction company are involved in the pre-construction process. Companies differ according to their business needs and size, however Box 3 shows the main departments and functions operating in a typical company.

The main stages in pre-construction are summarised in Box 4.

BOX 3

Main departments in a typical construction company

Task \ Department	Land buying	Consulting engineers	Group engineers	Regional design team	Company HQ	Regional HQ	Solicitors	MMC manufacturer	Local planning consultant
Identify and assess potential sites	■	■	■	■					
Develop the business case	■				■	■	■		
Bid for, or purchase, land	■						■		
Produce concept design				■				■	■
Finalise layout/design				■				■	■
Obtain planning permission				■			■		■
Obtain approval for Building Regulations				■				■	

BOX 4

Main stages in pre-construction: private sector builders

Pre-construction steps	Top Tips
Identify and assess potential sites	Check planning constraints Identify site constraints Confirm market need Check services
Develop the business case	Produce outline plan for layout Produce profile dwelling types and numbers Consider most appropriate construction technology
Bid for or purchase land	Consider whether to purchase outright or make a conditional bid (eg subject to planning or soil survey)
Produce concept design	Confirm market research Complete site assessment (soil surveys, engineer's report, access restrictions) Engage local planning consultant If MMC to be used, consult manufacturer/supplier
Confirm business case	Reaffirm market research Confirm cost estimates
Finalise overall site layout/design	Work with planning officers
Obtain planning permission	Complete purchase of land if original bid conditional
Obtain Building Regulations approval	If MMC check for third party approved construction system

Housing associations

Because housing associations have potentially a much more diverse set of requirements for the dwellings they commission, the pre-construction phase is crucial to the success of the project. Box 5 highlights the sequence of activities.

Developing the brief

The brief sets out the parameters for the project in terms of what needs to be achieved. It is developed by a core team, typically comprising key members as shown in Box 6.

The brief (also known as employer's requirements) needs to be clear and unequivocal because it informs the MMC appraisal. A wide range of issues need to be covered including:

- number, mix and size of units to be built
- time frame in which scheme should be delivered
- capital and life cycle costs
- tenant needs or purchases that may go over and above minimum standards and regulations (eg security or access requirements for the elderly or disabled)

BOX 5

Main stages in pre-construction: housing associations

Pre-construction steps	Top Tips
Define need and develop project brief	Set up core briefing team Identify site constraints Set outline budget Develop brief
Appraise systems including estimates	Gain understanding of main principles of off-site production Determine assessment criteria Review all potential construction types
Assemble concept team	Consider need for off-site adviser
Produce concept design	Sufficient detail for visual impact Cost plan updated
Construction options/value appraisal	Decide whether to adopt off-site production Stage 1 pre-tender estimate
Assemble project team	Decide to include off-site manufacture under two-stage tender
Detailed construction appraisal	Last opportunity for changes Pre-tender estimate Select manufacturer for off-site housing
Develop preferred option	Details from selected manufacturer used to finalise details and optimise production
Obtain planning permission	Innovative designs are less likely to gain planning consent so allow sufficient time
Obtain approval for Building Regulations	Could be a third party approved construction system
Schedule production	Detailed programme planning essential for off-site assembly
Finalise design details	Consider early design freeze to improve planning and predictability Check for insurability and warranty issues

BOX 6

Summary of core team responsibilities in a housing association

Core team member	Responsibility
Developer (if not RSL – registered social landlord)	Overall scheme concept
Finance director	Budget and funding
Architect/surveyor	Site issues and design
RSL development officer	Policy issues
Housing manager	Tenant needs
Employer's agent	Independent quality control
Valuer	Rental and other income

- town and country planning issues which are known at this stage, eg conservation issues, height restrictions and density issues
- the organisation's own strategy plan
- required performance of the finished product (running/energy costs, maintainability, robustness)
- location and layout of the site (access, topography, existing services, neighbourliness during construction)
- business case
- environmental issues.

The outputs from this stage should include:

- schedule of site constraints
- list of criteria that the development must fulfil
- schedule of dwelling sizes
- budget and time limits
- hierarchy of needs and assessment criteria.

Assessing construction options

Using the assessment criteria, construction options should be assessed to determine how well they each meet the brief. Constraints that limit the use of a particular form of construction may be wider than those imposed by the project brief – the lists below can be used to supplement the brief.

Site conditions

Including:

- crane and transport access
- storage
- overhead electric cables.

Time frame

- find out when the client will need to enter into financial and contractual commitment
- consequences of delays to site-based tasks.

True cost of alternative solutions

- compare the cost of different options on a realistic basis – the build costs are only part of the equation – innovative systems which take less time to construct on-site can lead to savings on, eg site prelims and equipment hire
- be aware that cashflow may differ for different construction types – MMC may require an increased 'up front' investment compared to conventional construction, but earlier completion may allow earlier income from rents
- consider whole life costs, eg future maintenance costs will differ for different systems.

Design constraints

Including:

- height of building
- spans
- repetition
- balconies
- cantilevers.

The assessment process should ideally be facilitated by an independent facilitator to ensure objectivity. If the organisation procuring the dwellings is new to MMC, it would be prudent to invite an MMC adviser to provide expert input. At this stage, the technology options to use in construction may only be reduced to two or three, rather than a single option.

Certification

Consideration should be given to the long-term interests of the mortgage lender, household insurer and the warranty provider, all of whom have an interest in the dwellings once they have been built.

Insurers in particular are interested in construction technology from the point of view of the cost of repairs and reinstatement in cases of damage. If the construction type is relatively novel, consideration should be given to whether or not the construction system chosen should have third party certification. Certification is necessary for some systems more than others – the more unusual the system the more likely it is that certification will be needed. Insurers or warranty providers may prefer certification if the product or full construction system:

- uses novel materials
- uses novel design or construction approaches
- uses standard materials from unknown suppliers
- is not fully covered by British or European standards for its manufacture and construction on-site
- claims performance characteristics beyond current accepted standards or outside the scope of current standards.

The need for certification will depend on whether a product or system is being considered and may cover:

- structural and fire performance
- thermal and acoustic properties

- durability
- repair and maintenance
- installation.

If the system is covered by certification make sure that:

- the proposed application is within the scope of the certificate
- certificates carry the UKAS logo or a notified body number
- the standard details are appropriate to the project.

Developing the concept design

A concept team develops the concept design – Box 7 outlines the make-up of a typical concept team.

Concept design covers issues such as visual impact and infrastructure issues which may impact on the cost plan. The MMC adviser's input is crucial if more than one construction option is still under consideration. Final appraisal of remaining construction options should take place at this stage, before the full project delivery team is assembled.

BOX 7

The concept team

Member	Responsibility
Cost consultant	Budget setting
Architect	Planning consultation, indicative site layout
Project manager	Co-ordination, programming, contract management
RSL development officer	Corporate and strategy issues
Housing manager	Tenants' needs
Employer's agent	Independent quality control
Valuer	Expected income
MMC adviser	Process and logistics advice
Main contractor	Programme, logistics and technical advice

Assembling the project team

To a certain extent the composition of the project team will depend on the method of construction chosen. The greater the level of off-site manufacture, the more important it is to get the manufacturer involved as early as possible. The first task for the project team is to select the manufacturer so that details can be finalised and production optimised. This may be an iterative process involving discussions initially with a number of potential manufacturers before making the final choice. It is important that the manufacturer is involved in the final stages of developing the design concept, particularly for highly manufactured solutions.

Roles and responsibilities for the project team should be agreed from the outset. A comprehensive list of items for consideration and team responsibilities is provided in the Annex. A summary of key project team members is shown in Box 8.

Obtaining approvals and developing the detailed design

Once the concept design is agreed, planning consent can be obtained. Manufacturers should confirm that the concept fits with their factory processes and standard detailing.

BOX 8

Summary of key project team members

Member	Responsibility
The core team brought together at project inception, including an MMC adviser and main contractor	Project management and co-ordination of project team including sub-contractors
Sales consultant (if there are units for sale)	Marketing
Designer	Compliance with Building Regulations and other legislation and interface considerations
MMC manufacturer	Shop drawings, production
Groundworks contractor	Foundations, drainage, roads, external works
Main contractor (may be manufacturer if conventional construction is not included)	Co-ordination of contractors, preparation of valuations
M&E and other specialists	As required

They can work with the design team to produce a detailed design that can be manufactured efficiently.

It is important to note that although it is desirable for manufacturers to be involved at this stage they may not have a formal contract to start building until the detailed design is finalised. This process should be discussed with them to agree the extent of 'at risk' work that they may have to do, and their payment expectations for work carried out before a formal contract is signed. A two-stage contract may be the most appropriate way forward.

Once developed, the detailed design is put forward for planning consent and approval under Building Regulations. In developing the detailed design the team should be aware of any planning restrictions, the constraints that the manufacturer works under, and the information the manufacturer will require. Some of the main considerations will be:

- Is there an understanding of the constraints and benefits of the MMC systems being used?
- Does the MMC manufacturer have a design guide?
- Have manufacturer's design details been obtained?
- Are there any structural requirements that may need consideration?
- What is and is not included within the system, eg cladding, services, windows, and floor cassettes?
- Is the design optimised in terms of efficiency and cost?
- What timescale does the MMC system need for design and manufacture before delivering?
- When is the design freeze date?
- Does the specification recognise the MMC supplier's efficiencies?
- Does there need to be a range of styles, layouts and colours?

Some aspects of the design are critical to the construction process. It is important to agree who is responsible for the detailed design of the interfaces between the factory-made parts and those assembled on-site. Both parties must be aware of, and accept as reasonable, the tolerances that each party is working to and each other's expectations. The detailed design of such interfaces must be critically reviewed by all concerned for buildability before being finalised.

PROCUREMENT

When letting the contract for the manufacture of units it is important to agree the following with the manufacturer:

- a date for the design freeze
- a timetable for delivery of the units (remember the manufacturer will not want to store units at the factory and will expect the site to be ready to accept delivery at an agreed time)
- period of notice required by the manufacturer to check that tolerances on-site are within agreed limits
- penalties for late delivery
- penalties for delays imposed on the manufacturer (eg if the site is behind schedule and not able to accept delivery at the agreed time)
- the tolerances and standards that the units need to be manufactured to (a mock-up/prototype may be the best way of agreeing this in order to avoid disputes)
- a formal procedure for checking the units before accepting handover
- a period for latent defects liability
- the extent of the manufacturer's responsibilities on-site during the erection/installation of the units, and requirements/conditions during that period.

Roles and responsibilities of parties involved in off-site manufacture

Process	Architect	Engineer	Contractor	Manufacturer
Design				
Specification of external/internal finishes	✔	–	–	✔
Specification of modular construction details	■	✔	–	✔
Loading	■	✔	–	✔
Co-ordination of structure and services	✔ (in building)	✔	■	✔ (within modules)
Co-ordination of elevational dimensions	✔	■	■	■
Overall dimensions	✔	■	✔	✔
Integration of internal drainage	■	–	✔	✔ (within modules)
Modular wall floor/ceiling construction	■	■	–	✔
Installation				
Requirements for lifting/installation	–	■	■	✔
Transportation requirements/arrangements	–	–	■	✔
Temporary site protection	■	–	■	✔
Foundations interfaces	■	✔	✔	✔
Cladding interfaces	✔	■	■	✔
Fire safety	✔	■	■	✔
External service connections	✔	–	✔	■
Maintenance requirements	✔	–	■	✔
Requirement for temporary propping	–	✔	✔	✔
Planning/regulations				
Planning issues	✔	–	–	–
Building Regulations applications	✔	✔	–	✔
Performance specifications	✔	✔	■	✔
CDM regulations	✔	✔	✔	✔
Demonstration of compliance with performance specifications	■	■	✔	✔
Monitoring production quality	✔	■	■	✔

✔ Duty* ■ Of interest

*Note: Duties need particular attention, careful co-ordination and definition when shared between parties.

A guide to modern methods of construction

This guide provides an accessible introduction to modern methods of construction. It will help developers, house builders, architects, planners and manufacturers to understand the variety of systems available and to appreciate how they can take advantage of the speed of construction and design opportunities they offer.

As a result of the growing demand for housing, Government is encouraging the house building industry to innovate and develop new solutions and ideas. Modern methods of construction are the key to meeting the demand for efficient, sustainable housing.

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The NHBC Foundation has been established by NHBC in partnership with the BRE Trust. It facilitates research and development, technology and knowledge sharing, and the capture of industry best practice. The NHBC Foundation promotes best practice to help builders, developers and the industry as it responds to the country's wider housing needs. The NHBC Foundation carries out practical, high quality research where it is needed most, particularly in areas such as building standards and processes. It also supports house builders in developing strong relationships with their customers.

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