National Audit Office

Using modern methods of construction to build homes more quickly and efficiently

REPORT BY THE NATIONAL AUDIT OFFICE | November 2005

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The National Audit Office team comprised Raymond Fawcett and Kerry Allison, under the direction of David Corner

The organisations on this page worked with us on the project (see Annex for more details)

For further information about the National Audit Office please contact:

National Audit Office
Press Office
157-197 Buckingham Palace Road
Victoria
London
SW1W 9SP

Tel: 020 7798 7400

Email: enquiries@nao.gsi.gov.uk

Office of the Deputy Prime Minister
Creating sustainable communities

HOUSING CORPORATION

scri

BCIS

mtech GROUP

The Housing Forum

CONSTRUCTING EXCELLENCE

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CONCERTO CONSULTING

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Photographs courtesy of South Somerset Homes

EXECUTIVE SUMMARY

1 This report is about how modern methods of construction can be used to build good quality homes more quickly and efficiently.

2 The Office of the Deputy Prime Minister and the Housing Corporation asked us to undertake an independent examination to identify how to get best value when using modern methods of construction. The aim is to provide practical help to Registered Social Landlords and private developers.

3 Our research has drawn on expert knowledge contributed by 50 leading sector practitioners in four workshops, together with further detailed information from over 20 organisations active in the home building industry.

4 Our key conclusions are that, when using modern methods of construction rather than more established techniques:

- it should be possible to build up to four times as many homes with the same on-site labour;
- on-site construction time can be reduced by over a half;
- building performance can be at least as good;
- cost ranges are comparable depending on specific project circumstances, although they are higher on average;
- risks increase at early stages of the development process so good risk management becomes even more important;
- tight liaison with planning authorities is vital; and
- benefits will be wasted if projects are not properly planned.

5 This report, with more detailed material available on an accompanying CD-ROM and on our website at www.nao.org.uk, provides a firm basis for further improvements in using modern methods of construction. The background material, which includes a set of sample project plans, is an invaluable starting point for any organisation considering how to introduce modern methods of construction. We invite others, in particular the Housing Forum in the role expected to be proposed by the Barker 33 Group[1], to develop the results described in this report and in the supporting material.

1 The Home Builders Federation convened the Barker 33 Group to take forward recommendation 33 calling for the development of a strategy to address barriers to modern methods of construction from 'Review of Housing Supply: Delivering Stability – Securing our Future Housing Needs, Final Report' by Kate Barker, March 2004. The final report of the Barker 33 Group is being published in winter 2005/06.

PART ONE
Introduction

1.1 The government is committed to promoting the use of modern methods of construction in home building **(Figure 1)**. In particular, the Office of the Deputy Prime Minister and the Housing Corporation spend £1.1 billion a year on building affordable housing using modern methods of construction, including £0.5 billion using off-site manufacturing approaches.[2]

1 Government bodies have an interest in modern methods of construction

Housing Corporation (sponsored by the Office of the Deputy Prime Minister)	Spends £1.6 billion a year (rising for future years) on building new social housing, with a target of 25 per cent to be modern methods of construction
English Partnerships (sponsored by the Office of the Deputy Prime Minister)	Encourages modern methods of construction across all its programmes and particularly in exemplar projects such as the Millennium Communities programme. Is running a competition to build homes for £60,000 or less, with many short-listed entries involving modern methods of construction.
Department of Trade and Industry	Promotes innovation in industry, including modern methods of construction

Source: National Audit Office summary

Modern methods of construction

1.2 The Office of the Deputy Prime Minister defines modern methods of construction as a process to produce more, better quality homes in less time. For the purpose of awarding grants, the Office of the Deputy Prime Minister uses a definition in terms of products.[3]

- Panellised units are produced in a factory and assembled on-site to produce a three dimensional structure. Open panels consist of a skeletal structure only, whereas more advanced panels may include lining material, insulation services, windows, doors, internal wall finishes and external claddings.
- Volumetric construction involves the production of three-dimensional modular units in controlled factory conditions prior to transport to site.
- Hybrid techniques combine both panellised and volumetric approaches. Typically, volumetric units (sometimes referred to as pods) are used for the highly serviced and more repeatable areas such as kitchens and bathrooms, with the remainder of the dwelling or building constructed using panels.
- Other modern methods of construction may use floor or roof cassettes, pre-cast concrete foundation assemblies, pre-formed wiring looms, and mechanical engineering composites. They can also include innovative techniques such as tunnel form or thin-joint block work (see section 2.13).

2 Figures for 2004-05 from the Housing Corporation's CORE database.
3 Office of the Deputy Prime Minister: Housing, Planning, Local Government and the Regions Select Committee - Eighth Report; supplementary memorandum by the Office of the Deputy Prime Minister (THC01(b)); July 2004.

1.3 A recent report from the industry defines modern methods of construction in terms of activities and outcomes as well as products.

- Modern methods of construction are about better products and processes. They aim to improve business efficiency, quality, customer satisfaction, environmental performance, sustainability and the predictability of delivery timescales. Modern methods of construction are, therefore, more broadly based than a particular focus on product. They engage people and process to seek improvement in the delivery and performance of construction.[4]

1.4 This report draws on both definitions of modern methods of construction. We examined behaviours and processes necessary to maximise construction efficiency when using the product types outlined by the Office of Deputy Prime Minister.

The search for value

1.5 The Office of the Deputy Prime Minister and the Housing Corporation asked the National Audit Office to investigate the scope for building homes more quickly and efficiently using modern methods of construction. Five particular issues provide the background to this request:

- the Office of the Deputy Prime Minister has a Public Service Agreement target to achieve a better balance between housing availability and demand;
- the Sustainable Communities Plan aims to develop a new approach to building in order to accelerate housing provision;
- the Barker report indicated that the higher costs of modern methods of construction restricted incentives to change building techniques;[5]
- there is widespread anecdotal evidence that building processes are not changing sufficiently to get the best out of modern methods of construction; and
- the Barker 33 Group has been examining barriers to the greater use of modern methods of construction in response to the Barker report.

1.6 The search for best value in homebuilding is not simply a question of finding the lowest cost. It is vital to maintain and enhance quality, including those aspects of quality that affect durability, lifetime running costs and overall performance in areas such as environmental sustainability. In addition, the government's policy to increase housing supply[6] requires more homes to be built in a shorter time, so value in homebuilding means building more quickly as well as more efficiently.

The National Audit Office study

1.7 The aim of our study has been to identify existing good practice, to promote its wider use and to encourage further improvement. We have paid particular attention to the affordable housing sector, because of the special interests of the Housing Corporation and Office of the Deputy Prime Minister, but our results and conclusions are relevant to the wider homebuilding industry. The annex to this report sets out the details of our methodology.

1.8 We consulted a wide range of experts and practitioners to gain a comprehensive view of current practice across the homebuilding sector, including:

- detailed reports and advice from consultants, whose expertise covers construction process modelling, building costs, modern methods of construction, building activity observation and building durability;
- workshops involving around 50 participants active in modern methods of construction and housing more generally, including developers, manufacturers, Registered Social Landlords, architects and consultants;
- discussion with a range of practitioners who provided detailed project plans and information on costs; and
- information about observed activities on building sites from the CALIBRE™ database maintained by the Building Research Establishment.

4 Analysis of the barriers to the greater use of Modern Methods of Construction in the provision of new mixed tenure housing and the solutions on how to overcome them, Barker 33 Cross-Industry Group, Draft Report; November 2005.
5 Review of Housing Supply: Delivering Stability – Securing our Future Housing Needs, Final Report; Kate Barker; March 2004.
6 Housing policy: an overview; HM Treasury and Office of the Deputy Prime Minister; July 2005.

1.9 We compared the building processes used by leading sector experts for different construction methods.

- We focused on five construction types: brick and block, open panel, advanced panel, hybrid and volumetric. We also examined thin joint block work as a variant of brick and block representing a modern method of construction not involving off-site manufacture.
- We took established brick and block processes as a reference point against which to compare modern methods of construction. We assessed where processes needed to change to reflect the requirements of each alternative construction method.
- We compared data from existing practice by examining their application to a hypothetical mixed development of 22 homes in flats and terraced housing, typical of recent affordable housing developments across England as a whole. We considered the effect of variation from our development, including much larger developments, by scenario analysis.
- We ensured consistent quality by defining standard performance requirements and interpreting them appropriately for each construction method.

Our results

1.10 The result of our work is to identify typical good practice in commissioning different construction methods and to compare how good practice changes to fit the construction method. The heart of this work is a set of process maps. These maps, along with other extensive material prepared by our partners for this study, are available in detail on our website and the accompanying CD-ROM.

- Our study identifies good practice by illustrating how leading sector practitioners are using different modern methods of construction. It is not optimum practice, because existing practice is invariably capable of improvement. It is a practical indication of what any residential developer should be able to do now.
- Our study identifies typical good practice in the same way that it is possible to describe a typical or average family. No family matches the average, because families vary greatly. In the same way, it is unlikely that our typical process models precisely match the current practice of any individual developer. This is because working preferences vary among developers, while the level of factory completeness in off-site manufactured products also differs among manufacturers, requiring variations in on-site construction processes. Our models usefully represent mid-points for a range of developers and manufacturers, and they can serve as a starting point for constructing process plans applicable to any specific site.

1.11 The study focuses on benefits that accrue to developers of new homes. We have not assessed public good benefits that could accrue from building more homes faster, such as cost savings to the public purse from reducing homelessness more quickly.

1.12 This report describes:

- the labour and time benefits from modern methods of construction, provided the process matches the building techniques (Part 2);
- the extent of cost variations between building methods, and the scope to reduce them (Part 3);
- an examination of quality issues (Part 4); and
- how risk management needs to change when using modern methods of construction (Part 5).

PART TWO
Labour and time

"Over one million more households were formed in England between 1996 and 2003, an increase of more than 5 per cent compared with a population rise of just 2 per cent. This trend is set to continue.

Since the 1960s the total number of homes built in the UK has been on a downward trend.

Since 2001, house building has begun to recover, with housing completions up by almost 20 per cent in 2004 compared to 2001. However, new house building is still not enough to meet demand, exacerbating upward price pressures."

Her Majesty's Treasury and Office of the Deputy Prime Minister, July 2005[7]

2.1 Modern methods of construction should make it possible to build more with the same amount of on-site labour. They reduce on-site construction time, including the time taken to achieve weather tight conditions. Process plans must suit the construction method in order to secure these labour and time benefits. Relationships with planning authorities become more critical when using modern methods of construction.

2.2 The chapter covers:

- labour savings;
- time savings;
- the importance of process planning;
- relationships with planning authorities, and
- other ways to obtain time savings.

Labour savings

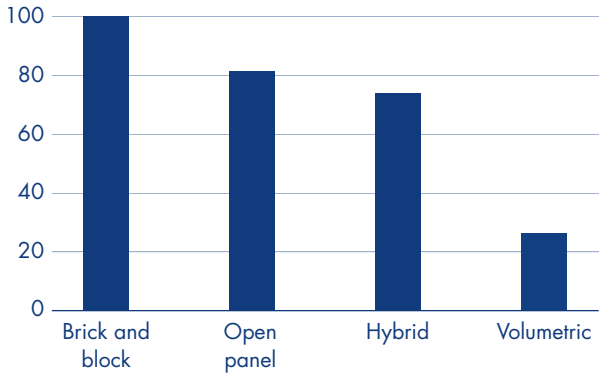
2.3 Many modern methods of construction use on-site labour less intensively than more established building methods. This is because part of the construction work is undertaken by a different workforce operating in factory conditions. In our example, a volumetric approach allowed a development to be completed with a quarter of the on-site labour required using more established methods **(Figure 2)**. Even greater labour savings may be possible if claddings other than brick are acceptable.

2.4 Modern methods of construction make it possible to build up to four times as much using the same on-site labour. This is crucially important when work for the London Olympics, coupled with a policy to build more homes, will place increasing demands on existing resources. There is uncertainty about whether on-site labour supply will increase to match higher demand, particularly in the light of recent reports from the Chartered Institute of Building of existing widespread recruitment problems.[8] Modern methods of construction have the potential to provide more building work with existing on-site labour, particularly as factory based production does not generally draw from the same labour pool as on-site construction and is not competing for the same skills.

7 Housing policy: an overview; HM Treasury and Office of the Deputy Prime Minister; July 2005, pp.24-26.
8 CIOB reveals results from skills shortage research; Chartered Institute of Building; Press Release; 15 August 2005.

2 Modern methods of construction require less on-site labour

Typical on-site labour days as a proportion of brick and block requirements (per cent)



Source: Process plans prepared for the National Audit Office by the Salford Centre for Research and Innovation

NOTE

Advanced panel methods give similar results to hybrid techniques in this particular development.

Time savings

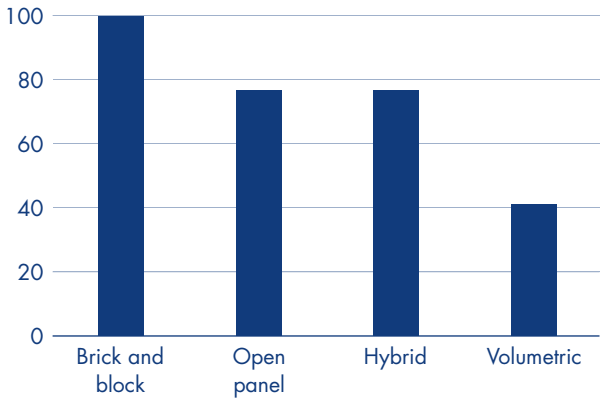
2.5 Modern methods of construction can halve the time spent on-site to build homes. In our example **(Figure 3)**, a volumetric approach reduced the on-site build time for the whole development to 16 weeks compared to 39 weeks for brick and block, with intermediate savings for other modern methods. Using alternative claddings can bring further time savings.

2.6 There are even more dramatic savings in the time taken to achieve weather tight structures: to as little as a quarter of the time taken using more established methods **(Figure 4)**. Obtaining weather tight structures quickly brings three major benefits:

- quality is protected because weather cannot damage what has already been built;
- bad weather cannot disrupt following trades; and
- working conditions are improved because the workforce is protected from rain and excessive cold or sun.

3 Modern methods of construction can halve on-site construction duration

Typical construction period as a proportion of brick and block requirements (per cent)



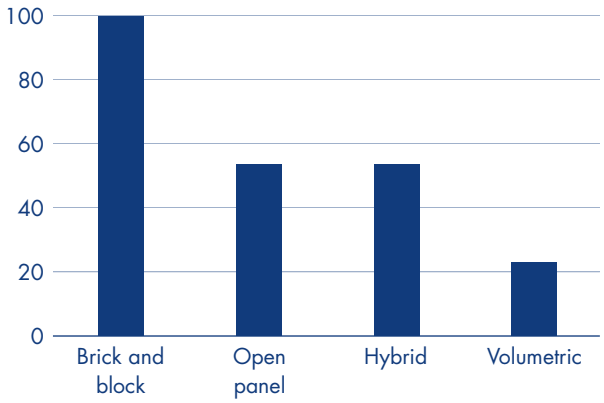
Source: Process plans prepared for the National Audit Office by the Salford Centre for Research and Innovation

NOTE

Hybrid techniques have a similar construction timescale to open panel in this example despite labour savings because most differences are not on the critical path. Advanced panel methods give similar results to hybrid techniques in this particular development.

4 Modern methods of construction provide weather tight conditions quickly

Typical time until weather tight as a proportion of brick and block requirements (per cent)



Source: Process plans prepared for the National Audit Office by the Salford Centre for Research and Innovation

NOTE

Hybrid techniques have a similar construction timescale to open panel in this example despite labour savings because most differences are not on the critical path. Advanced panel methods give similar results to hybrid techniques in this particular development.

The importance of process planning

2.7 The time and labour savings discussed above are available only if process plans are tailored to match the method of construction and are followed appropriately. Our results are based on detailed process plans prepared from the collective experience of participants in our workshops and further advice from developers and manufacturers with whom we held extensive discussions. The complete plans are too large to illustrate in this short report but they are available on our website and the accompanying CD-ROM. An extract illustrates the nature of the plans, in this case the activities necessary to complete the superstructure for one house using an open panel approach **(Figure 5)**. The main stages of the full plans are:

- foundations;
- superstructure;
- internal works; and
- completion.

2.8 Our process plans demonstrate how requirements change for different construction methods. There can be variations in the timing of activities, including when workers need to arrive on site, the sequence of activities and the level of labour and other resources, such as scaffolding **(Figure 6)**.

6 Different construction methods have different requirements

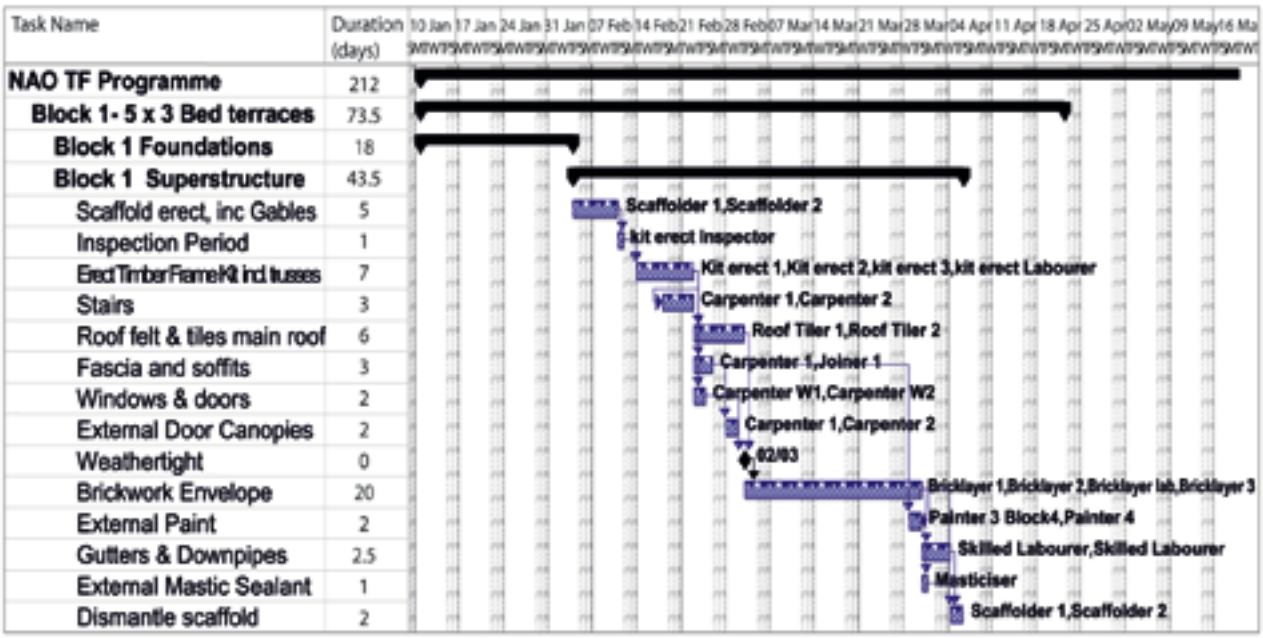
	Brick and Block	Open panel/ Advanced panel/Hybrid	Volumetric
Bricklayers on-site	44 days	20 days	20 days
Arrival of first following trades	16 weeks after groundbreak	7 weeks after groundbreak	Not used
Scaffolding in use	11 weeks	8 weeks	6 weeks

Source: Process plans prepared for the National Audit Office by the Salford Centre for Research and Innovation

NOTES

These requirements apply to our example development of 22 dwellings. Brick and block requires bricklayers to construct both the internal and external skin of a building, whereas other methods require bricklayers for the external skin only.

5 Process plans must match the construction method



Source: Process plans prepared for the National Audit Office by Salford Centre for Research and Innovation

NOTE

Extract showing the activities involved in building the superstructure of an open panel (timber frame) house.

Relationships with planning authorities

2.9 The most time-consuming development activities before on-site work can start include interactions with planning authorities. These interactions can have as much influence as construction itself over the time taken to completion. Planners therefore need to exercise the same discipline as developers if the benefits of faster construction are not to be wasted.

2.10 The relationship with planners is particularly important in keeping the design and manufacture of off-site components off the critical path. Failure to do this would replace on-site time savings by additional off-site time, wasting the time benefits of modern methods of construction. Modern methods of construction reduce on-site construction time precisely because some of the construction work takes place earlier in a factory. Factory work will not increase total development time provided the design of manufactured elements starts as soon as outline planning permission is obtained. This allows design and subsequent manufacture to run in parallel with other activities that have to be undertaken regardless of the construction method. Later design changes cannot readily be implemented without influencing the production schedule and extending overall time.

2.11 Managing the relationship with planners depends on developing a long-term communication strategy. Planning authorities are often receptive to closer liaison with developers at early project stages, particularly through the use of design codes which encourage professional and technical collaboration. Recent guidance states that "councillors should involve themselves in discussions with developers, their constituents and others about planning matters. (They should) hold discussions before a planning application is made, not after it has been submitted to the authority".[9] Planning officials are often willing to provide a "recommendation of approval" several weeks before formal approval. This enables developers to commit to design, and consequently production, several weeks earlier than would otherwise be the case.

2.12 We discuss planning issues in greater detail in a joint report with the Audit Commission due to be published shortly.[10]

Other ways to obtain labour and time savings

2.13 It is possible to obtain savings in on-site labour and time using techniques that do not involve off-site manufacture. These techniques give scope to reduce on-site time by up to a third. Like other modern methods of construction, they require careful attention to process planning and subsequent adherence to the process programme. Process plans for these techniques are available in detail on our website.

- Thin joint construction allows the block element of external walls to be constructed quickly and, like panel approaches, before the external cladding is completed. This reduces total construction time, in part because there is an extra gang working on the block work while another gang completes the brick work. The technique also reduces labour requirements on the block work element because the gang can complete the work in a shorter time. As with other methods of construction, further labour and time savings may be possible if claddings other than brick are acceptable.
- A similar approach of adding a second gang to complete brickwork on another part of the site in parallel to the activities of the first gang could be taken with more conventional techniques. This gives time savings but does not reduce labour requirements.

9 Positive Engagement - A Guide for Planning Councillors; The Office of the Deputy Prime Minister and the Local Government Association, 2005.
10 Building more affordable homes: Improving the delivery of affordable housing in areas of high demand; National Audit Office and Audit Commission, to be published December 2005.

PART THREE
Cost

> "At the present time, traditional brick and block methods of construction remain cheaper, in many cases, than modern methods of construction, including off-site manufacture. The time savings available do not currently provide a compelling financial reason to switch production."
>
> *Kate Barker, March 2004*[11]

3.1 There is a large overlap in the costs of different construction methods, so modern methods of construction can be at least as competitive as more established techniques in appropriate circumstances. Nevertheless, many modern methods of construction are still more expensive on average than established brick and block techniques. Open panel techniques provide an exception and are cost-competitive. The financial benefits of time savings go around a third of the way towards bridging the average cost gap for modern methods of construction. A potential reduction in the price of manufactured components as the market matures could close the cost gap.

3.2 This part covers:

- the relative costs of different construction methods;
- circumstances that favour or work against modern methods of construction;
- the financial benefits of faster construction and reduced on-site work; and
- the scope to bridge the remaining average cost gap.

Costs of different construction methods

3.3 Modern methods of construction other than open panel techniques continue to be slightly more expensive than more established techniques but the cost ranges for different techniques overlap substantially **(Figure 7)**. The large overlap means that, in any particular set of conditions, a modern method of construction could be as cost-effective as brick and block, or more cost effective. The next section explores the circumstances that can enhance or undermine the relative cost-effectiveness of modern methods of construction.

3.4 The calculated cost ranges confirm what is emerging from the competition sponsored by the Office of the Deputy Prime Minister and English Partnerships to build a home for £60,000. The target cost of £784 per m^2 for that competition is a challenge but is within the reach of modern methods of construction.

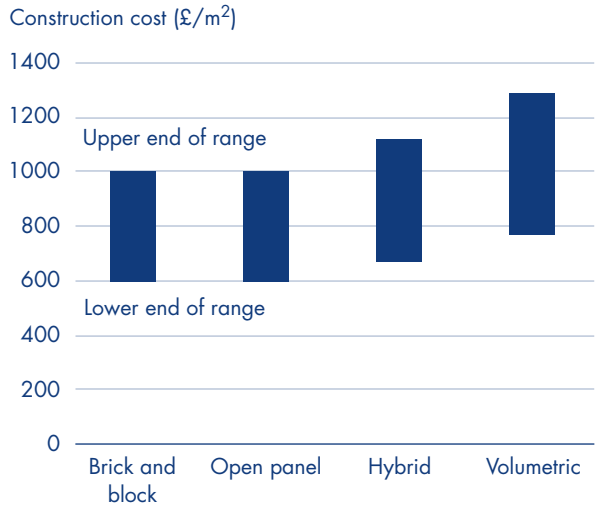
Circumstances that favour or work against modern methods of construction

3.5 Some circumstances improve the cost-effectiveness of modern methods of construction relative to more established techniques while others work in the opposite direction. Our study considered a wide range of scenarios to examine the impact of conditions that can vary from one development to

11 Review of Housing Supply: Delivering Stability – Securing our Future Housing Needs, Final Report; Kate Barker; March 2004 p.113.

another. On the basis of practitioners' collective experience shared in our workshops, we identified those circumstances that most affect the relative cost-effectiveness of modern methods of construction **(Figure 8)**.

7 Modern methods of construction tend to be more expensive than more established techniques but the ranges overlap



Source: Cost calculations prepared for the National Audit Office by the Building Cost Information Service using process plans developed by the Salford Centre for Research and Innovation

NOTE

Cost is calculated from the process model for a range of suppliers for each method. The average cost is then converted to a range based on the inter-quartile range of a survey of projects – the costs shown cover dwellings only, with preliminaries allocated between dwellings and external works in proportion to costs incurred before adding preliminaries. The more detailed report from the Building Cost Information Service describing these calculations is on our website and the accompanying CD-ROM.

Advanced panel methods give similar results to hybrid techniques in this particular development.

3.6 Typical affordable housing developments in major cities and in parts of the South East of England tend to be larger and involve more storeys than our example development. Private sector developments in general are also likely to be larger. Our scenario analysis concluded that higher buildings favour modern methods of construction because costs rise faster for brick and block than for off-site manufactured elements. Techniques such as concrete and steel frame also become more viable.

Financial benefits of faster construction and reduced on-site work

3.7 Faster construction and reduced on-site work bring financial benefits that go about a third of the way to offsetting average increased construction costs for hybrid and volumetric construction methods **(Figure 9)**. These financial benefits make open panel techniques more cost-effective overall than more established techniques. Four effects contribute to the financial benefits for Registered Social Landlords, with equivalent advantages applicable to private sector developers, including more precise control over time to market:

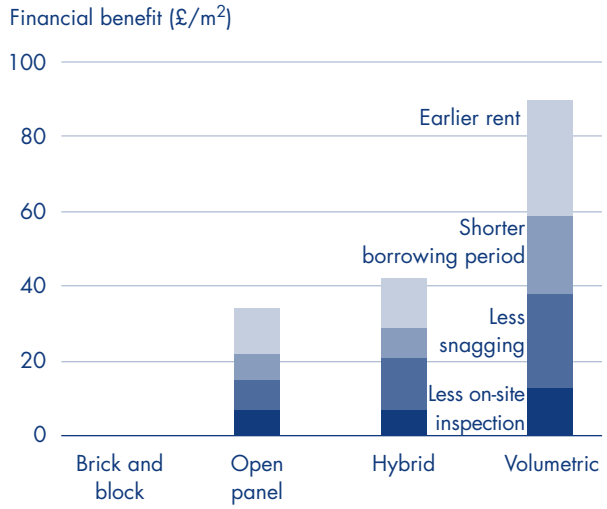
- rental income streams start earlier;
- Social Housing Grant can be drawn down earlier, reducing interest payments on capital to fund developments;
- snagging costs are reduced because off-site construction elements are subject to the tighter quality control made possible in factory conditions; and
- the need for on-site inspection decreases as the amount of off-site work increases.

8 Different project circumstances can favour or work against modern methods of construction

Circumstances that favour modern methods of construction	Circumstances that work against modern methods of construction
Poor soil conditions (favouring lighter buildings)	Late design changes
Restricted working space	No standard designs or designs not suited to modern methods of construction
More storeys	Late appointment of the contractor/supplier
Rooms in the roof (favouring panelised roofs)	No framework agreement with manufacturer
Acceptability of alternative cladding materials and roof designs	Requirement to suspend operations (a larger proportion of cost is committed earlier so there is less scope for postponing costs)

Source: Analysis of workshop scenario discussions prepared for the National Audit Office by the Building Cost Information Service

9 Faster construction and reduced on-site work brings financial benefits to developers



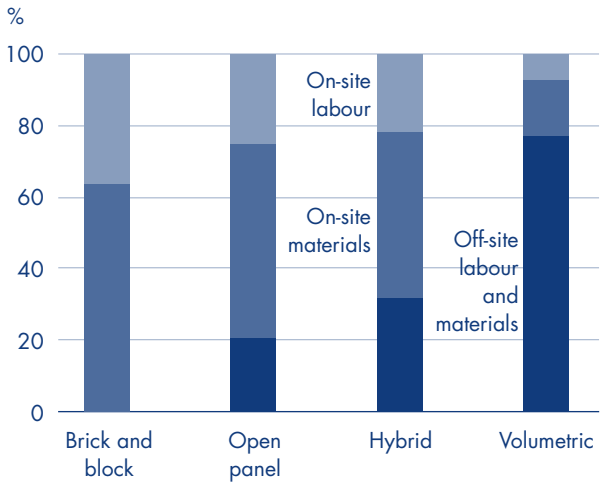
Source: Savings are expressed in relation to floor area to illustrate the extent to which they offset increased average construction costs expressed in the same terms.

NOTE

Cost calculations prepared by the National Audit Office using information provided by the Building Cost Information Service and process plans developed by the Salford Centre for Research and Innovation.

Advanced panel methods give similar results to hybrid techniques in this particular development.

10 Modern methods of construction increase the proportion of costs that are incurred off-site



Source: Cost calculations prepared for the National Audit Office by the Building Cost Information Service using process plans developed by the Salford Centre for Research and Innovation.

NOTE

Advanced panel methods give similar results to hybrid techniques in this particular development.

Scope to bridge the remaining average cost gap

3.8 The search for further cost reductions depends on where most costs occur, which varies for different construction methods **(Figure 10)**. The proportion of total construction cost that is incurred off-site increases substantially as the amount of off-site work increases. Cost is incurred mostly off-site for volumetric approaches and mainly on-site for other methods of construction. As a consequence:

- volumetric approaches will become more competitive only if the cost of the off-site element decreases; and
- hybrid approaches will become more competitive if either the cost of the off-site element decreases or if the off-site element contains sufficient added value to allow greater reduction in on-site labour and materials.

3.9 Delegates at our workshops estimated scope for a potential 15 per cent price reduction in off-site elements as a consequence of a maturing and expanding market for hybrid and volumetric approaches. Prices would inevitably follow an erratic course in relation to market expansion. The Building Cost Information Service estimates that most suppliers could cope with a doubling of demand by using spare capacity. Further increases in demand would lead to temporary price increases until more capacity became available, when prices would start to reduce again.

3.10 The impact of a 15 per cent price reduction is sufficient, in combination with financial savings for developers already discussed, to close the cost gap for modern methods of construction. The price impact is greater for volumetric methods than for hybrid because off-site elements account for a larger proportion of total cost.

PART FOUR
Quality

4.1 Modern methods of construction can deliver at least as good quality as more established building techniques, provided they are appropriately specified. Two reports that provide the basis for the summary in this chapter are available on our website and the accompanying CD-ROM, written for us by:

- Building LifePlans Ltd (specialists in durability and risk management); and
- the Building Cost Information Service (part of the Royal Institute of Chartered Surveyors).

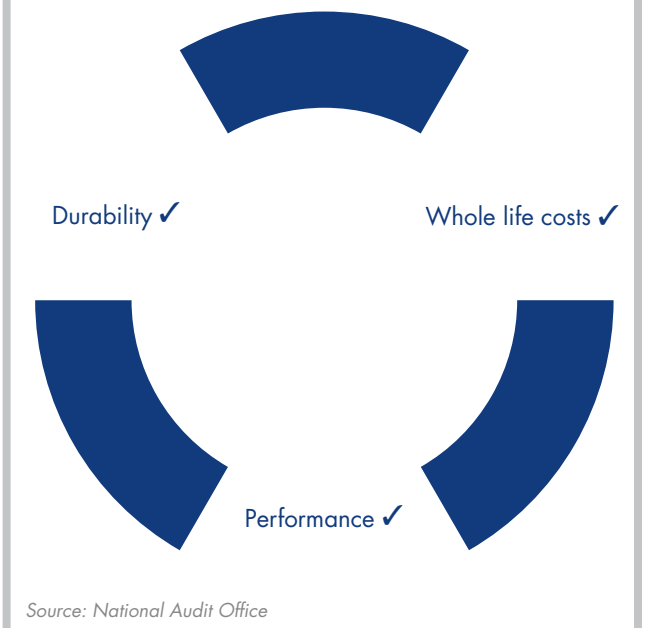
4.2 This chapter provides positive answers to the three major quality questions that can be posed about any home built by modern methods of construction when compared to a more traditionally constructed home **(Figure 11).**

- Will it last as long (durability)?
- Will it cost the same to maintain (whole life costs)?
- Will it operate as well (performance)?

Durability

4.3 We commissioned Building LifePlans Ltd to examine in detail the specifications for building our development with different construction methods. Building LifePlans Ltd has a specialist expertise in durability as part of a risk management process, and it uses this expertise to provide long term latent defects warranties.

11 Modern methods of construction meet the three key quality requirements



Source: National Audit Office

4.4 Building LifePlans Ltd concluded in its report that the expected durability of the development using each construction method is similar. In particular, all structural components have an expected life in excess of 60 years, which is the typical industry period for assessing expected component service lives. The report found that this "is expected, as the key components which are affected by degradation agents are the same for each construction type".

The durability assessment is based on ISO 15685, the standard for service life planning. The report notes that off-site manufacture may not guarantee enhanced durability but "factory production should reduce the risk of non-conformities, related premature failures and consequent repairs which may be associated with on-site assembly".

4.5 The detailed durability report from Building LifePlans Ltd lists the expected service life of each component in each building. It is available on our website.

4.6 The Building Cost Information Service concluded that the underlying structural materials used in modern methods of construction would continue to last well beyond any reasonable investment horizon. Masonry, concrete and timber buildings still exist that have given good service for many hundreds of years. On more recent innovations, the Steel Construction Institute has assessed light steel frame systems as having potential life spans of over 200 years.[12]

Whole life costs

4.7 The Building Cost Information Service reported to us that there are no maintenance issues with the underlying structures of homes built using modern methods of construction, for the reasons noted above in relation to durability. Materials are of similar or identical specification so will have the same durability and whole life cost. Maintenance regimes for components, such as windows, will be the same regardless of the building technique deployed because the specifications ensure that the components are the same.

4.8 The Building Cost Information Service considers that modern methods of construction bring a potential quality advantage because the controls available in factories can be tighter than those on-site. This is likely to lead to fewer components failing early due to incorrect installation or damage during on-site operations.

Performance

4.9 A range of standards aims to ensure that buildings will perform satisfactorily in use. We asked Mtech Group to design specifications for each construction method to meet the identical requirements in terms of relevant standards. Our development meets the following standards, regardless of the construction method deployed:

- accreditation by NHBC, Zurich or Building LifePlans;
- current Building Regulations, including Part L revision; and
- Housing Corporation scheme development standards compliant.

12 Building design using cold formed steel sections - durability of light steel framing in residential building; Popo-Ola SO, Biddle AR and Lawson RM; The Steel Construction Institute; Publication 262; 2000.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PART FIVE
Risk Management

5.1 Modern methods of construction change the risk profiles of home building projects. Some development risks become less significant in terms of likelihood of occurring and potential impact. Examples include price fluctuations during the construction process and delays due to bad weather. Other risks become more significant. Examples of these include unpredictable planning decisions and designs that are not suited to the construction method.

5.2 On balance, risks increase in the early stages of a project before on-site work starts. Risk management therefore becomes even more important when using modern methods of construction. Mitigating the risks requires process discipline, good coordination and a culture that will not accept late changes.

5.3 The remainder of this chapter expands on five specific risks during the development phase of a project that increase with modern methods of construction, ending with a table summarising development risk. The five risks described in more detail are:

- late design changes;
- loss of factory production slot/production capacity;
- inaccurate or unsuitable foundations;
- suppliers failing to deliver on time; and
- manufacturer insolvency.

Examples of managing specific risks

Late Design Changes

5.4 Late changes to design have a major impact on modern methods of construction because factory work, based on the designs, starts early: well before on-site work starts. Changes that lead to additional factory work can be costly and can cause delay, potentially leading to further costs in the form of time penalties. In contrast, established brick and block approaches can absorb design changes more easily, even after on-site construction is in progress.

5.5 It is vital to involve the supplier of manufactured elements from an early stage, working closely with the design team, architect and client to ensure the development is designed for manufacture. Close collaboration with planners is necessary to ensure that all issues that may impact upon design are resolved before product design is fixed.

Loss of factory production slot

5.6 Modern methods of construction carry the risk of losing a factory production slot. Finding another slot, particularly if the design is specific to one manufacturer or for a large volume of homes, can lead to lengthy delays. Loss of a slot can be caused by projects drifting beyond a planned start date or if lead times for certain products are underestimated.

5.7 The risk of missing a factory production slot can be reduced by effective communication between developer and manufacturer, giving factories sufficient warning to prepare for peak production periods. Greater standardisation and collaboration between groups of developers could also lead to flexibility in allocating production slots. Some Registered Social Landlords are currently exploring this possibility.

Inaccurate or unsuitable foundations

5.8 Modern methods of construction, particularly volumetric approaches, require foundations to be built accurately. Foundations that are out of tolerance need to be corrected before the factory elements can be installed. If errors are discovered late and there is limited storage space, elements may have to return to the supplier while foundations are corrected, introducing delay and extra cost. Delays at this stage would require timing changes to later processes, leading to the re-booking of other resources and potentially introducing further delay and cost.

5.9 The risk of inaccurate or unsuitable foundations can be minimised by providing appropriate education for on-site teams and ground workers, and by effective on-site management. Involving the manufacturer early and enabling them to inspect site and foundations before delivery can also reduce the likelihood of such an occurrence.

Suppliers failing to deliver on time

5.10 Modern methods of construction rely on factory manufactured elements being erected at the right time. Other work cannot proceed until these elements are in place. Failure by the supplier to deliver on time will delay projects and require other activities to be re-scheduled, with consequent increases in time and cost.

5.11 The risk of failure to deliver on time can be mitigated in general by effective supply chain management. In addition, a focused approach will identify long lead time items early and make sure orders are placed in adequate time. Good processes, such as ISO 9000, are vital.

Manufacturer insolvency

5.12 Manufacturer insolvency during the course of a project would have major implications for modern methods of construction. If the design and production of many building components, particularly pods and panels, are specific to one manufacturer then the choices are to alter the project substantially or to seek another manufacturer prepared to make a compatible product. Either action is costly and causes delay. The effect of insolvency would have greater impact the later into a development it occurs.

5.13 The risk from manufacturer insolvency can be minimised by standardisation across manufacturers. Developers should ensure that procurement processes are robust and efficient to minimise the disruption caused by the search for alternative manufacturers. Effective communication across the supply chain should alert developers to impending problems with manufacturers as early as possible.

Summary of the main development risks and their management

12 Modern methods of construction change the development risk profiles

Process stage	Risk description	Brick and block	Open panel	Hybrid	Volumetric	Mitigating action
Planning	Unpredictable planning decisions	🟢	🟢	🔴	🔴	■ Early and extensive consultation with planning authorities ■ Education of design team and planners in capabilities of different build methods ■ Design coding
Pre-construction	Losing factory production slot/production capacity	🟢	🟡	🔴	🔴	■ Effective supply chain management stabilises workflow to factory ■ Manufacturer sets up overtime working or starts additional shift
Pre-construction	Late appointment of contractor/manufacturer	🟢	🟡	🔴	🔴	■ Efficient developer procurement processes ■ Long-term working relationships with contractors or clients
Pre-construction	Design not suited to construction method	🟢	🟢	🔴	🔴	■ Assemble competent and experienced team early in process ■ Effective communication across supply chain
Pre-construction	Lack of standardisation	🟢	🟡	🔴	🔴	■ Use standard dimensions or shells ■ Effective communication across supply chain
Detail design and production information	Design changes after order placement/product information stage	🟢	🟡	🔴	🔴	■ Early involvement of manufacturer in design ■ Effective communication across supply chain
Construction	Foundations inaccurate/ unsuitable	🟢	🟡	🟡	🔴	■ Pre-inspection by system manufacturer ■ Education of groundworker and main contractor ■ Better site management
Construction	Suppliers fail to deliver on time	🟢	🟢	🔴	🔴	■ Effective communication across supply chain ■ Identify long lead items early ■ Good processes in place to manage, e.g. ISO 9000
Construction	Suppliers fail to deliver correct components	🟢	🟢	🔴	🔴	■ Effective communication across supply chain ■ Good processes in place to manage, e.g. ISO 9000 ■ Standardisation

🔴 High risk
🟡 Medium risk
🟢 Low risk

12 Modern methods of construction change the development risk profiles (continued)

Process stage	Risk description	Brick and block	Open panel	Hybrid	Volumetric	Mitigating action
Construction	Manufacturer insolvency	Low risk	Medium risk	High risk	High risk	■ Standardisation ■ Effective communication across supply chain ■ Select quality and experienced manufacturers ■ Efficient developer procurement processes
Construction	Damage to key pre-assemblies or critical components	Low risk	Medium risk	High risk	High risk	■ Good route planning and experienced haulage contractors ■ Educate site management teams ■ Site security ■ Avoid storage on site if possible
Construction	Modern methods of construction and traditional components incompatible	Low risk	Low risk	High risk	High risk	■ Education of design team ■ Experienced manufacturers with good design resources ■ Effective communication across supply chain ■ Standardisation
Construction	Quality problems with product	Medium risk	Low risk	Low risk	Low risk	■ Select quality and experienced manufacturers ■ Check manufacturer's Quality Management System status (ISO 9001 or 9002) ■ Third party factory inspection ■ Bespoke quality specifications for the project
Construction	Price fluctuations during the construction phase	High risk	Medium risk	Low risk	Low risk	■ Partnering and open book approach ■ Effective communication across supply chain
Construction	Delays due to bad weather	High risk	Medium risk	Low risk	Low risk	■ Education and awareness of site teams ■ Contingency plans to cover windy days ■ Alternative on-site storage arrangements
Construction	Lack of key trade skills	High risk	Medium risk	Low risk	Low risk	■ Skills training programmes with constructor partners ■ Long term relationships with approved suppliers ■ Process and specification changes to reduce reliance on scarce trade skills
Construction	Service installation faults	High risk	Medium risk	Low risk	Low risk	■ Clear communication of business need and build strategy during planning stage ■ Training of workforce or use of manufacturer's installation teams ■ Quality control review during site assembly

● High risk ● Medium risk ● Low risk

12 Modern methods of construction change the development risk profiles (continued)

Process stage	Risk description	Brick and block	Open panel	Hybrid	Volumetric	Mitigating action
Construction	Health and safety hazards	High risk	Medium risk	Low risk	Low risk	■ Good site management and operative education and training ■ Continuity of supplier partnerships ■ Training and awareness programmes of changes in working practices
Occupation and review	Completed construction does not match specification	High risk	Medium risk	Low risk	Low risk	■ Good design co-ordination and integration ■ Effective communication across supply chain ■ Training and awareness programmes of changes in working practices
Occupation and review	Defects at handover/ during liability period	High risk	Medium risk	Low risk	Low risk	■ Good site management and project KPI benchmarking ■ Continuity of supplier relationships ■ Training and awareness programmes of changes in working practices ■ Consider only those systems that have a BBA or BRE Certification

Source: Views expressed at workshops, summarised and amplified for the National Audit Office by Mtech Group

ANNEX
Methodology

1 We designed our methodology to analyse and compare results from recent home building developments using a range of construction methods. Our study involved:

- appointing a broad range of specialist consultants to advise us on construction process modelling, building cost calculation, modern methods of construction, on-site activities and durability assessment;
- holding four workshops involving around 50 practitioners, including developers, manufacturers, Registered Social Landlords, architects and consultants, to share knowledge and comment on the direction of our study;
- holding ongoing and detailed discussions with further practitioners, particularly Registered Social Landlords and manufacturers, to map and cost typical development processes;
- securing information from a database of observations of on-site activities;
- normalising results to aid comparison and to ensure consistent building quality using a hypothetical development typical of those undertaken by Registered Social Landlords in England; and
- consulting two expert groups on emerging results.

Specialist consultants

2 We appointed seven consultant organisations to work as an integrated team alongside our own staff.

Workshops of practitioners

3 We held a series of four workshops of practitioners to provide critical feedback on build specification, project plans and cost models to ensure they were firmly rooted in the practical realities of construction. These events allowed us to draw upon a wide range of expertise in the sector.

Further consultation with practitioners

4 Our consultants conducted extensive interviews with a wide variety of practitioners to add detail to information obtained from workshops.

Database of observed processes

5 Our consultants used information from the CALIBRE™ database, which the Building Research Establishment created to record activities on building sites. The tool provided examples of observed processes and schedules to complement material obtained from workshops and stakeholder consultation. It helped us to map resource allocation and activity duration.

Our consultants

Consultant	Role
Stuart Carmichael, Ken Treadaway and John Hobson **Salford Centre for Research and Innovation, University of Salford**	Mapped the processes for each method of construction based on an existing process protocol. Developed detailed maps including a resource-loaded breakdown in the construction process from conception to completion, including high-level strategic activities
Joe Martin and Amadeus Martin **Building Cost Information Service at the Royal Institute of Chartered Surveyors**	Provided best estimates of total costs to practical completion for each building method as defined by the process maps. Also provided a survey of current project costs and tested a variety of different scenarios to identify the cost and time sensitivity of each construction approach to various factors including health and safety, weather, building regulations improvements, snagging and rework, and volume
Martin Goss **Mtech Group**	Provided technical expertise in designing physical specifications for each build method and completed a risk analysis
Judith Harrison and Krystyna Blackburn **Housing Forum**	Convened workshops using extensive contacts within the home building industry
Peter Mayer **Building LifePlans Ltd**	Provided a durability assessment for the different construction methods
Keith Ross **Building Research Establishment**	Supplied data to assist with the programming of works on the development model, providing a check of overall process and resource allocation
John Forrester **Concerto Consulting**	Provided workshop facilitation

Normalising results

6 We defined a development to act as a reference point to compare results from a wide variety of sites. The Building Cost Information Service identified a typical Registered Social Landlord development across the whole of England as comprising 22 homes in terraced housing and low rise flats. Our workshops considered, among a range of scenarios, how results would change for larger and higher developments, such as those in major cities and parts of the South East and in the private sector. Our consultants translated observations from different recent developments to what they would have been if applied to this normalised development, hypothetically based in Northamptonshire as an area where house building conditions reflect national averages. In this way, we were able to compare observed results directly. We made the following assumptions about the normalised development, subsequently using scenario analyses to examine the effect of varying them:

- 10 houses (5 person 3 bedroom, 85.6m^2 two-storey houses in two blocks of five);
- 12 flats (3 person 2 bedroom, 64.2m^2 flats in two-storey blocks, one of 4 and one of 8 units);
- a standard brick cladding and roof design to give the same external appearance regardless of construction method;
- a standard trussed roof to promote comparability;
- a flat site adjacent to an existing street;
- a good access road with turnaround; and
- good ground conditions.

Expert panels

7 We invited two expert panels to comment on our preliminary results:

- the Barker 33 Group[13], comprising experts from the home building industry; and
- the development directors of the G15 group of Registered Social Landlords in London.

13 The Home Builders Federation convened the Barker 33 Group to take forward recommendation 33 calling for the development of a strategy to address barriers to modern methods of construction from 'Review of Housing Supply: Delivering Stability – Securing our Future Housing Needs, Final Report' by Kate Barker, March 2004.

Our workshops

Workshop participants	Organisations
John Glover	Barratt East London
David Lowther	Bovis Homes
Tim Grindley	BRE
Michael Driver	Brick Development Association
Ali Arasteb	Brick Development Association
Tom de Saulles	British Cement Association
Simon Main	Building LifePlans Ltd
Jeff Maxted	Building LifePlans Ltd
Andy McCosh	Calfordseaden
Chris Moquet	Calfordseaden
David Doherty	Circle Anglia Housing Association
Alistair Jones	Circle Anglia Housing Association
Francis Ryder	Concrete Centre
Stephen Smith	Concrete Centre
John Tebbit	Construction Products Association
Richard Dixon	Corus
Penny Stern	English Partnerships
Paul McGivern	English Partnerships
Andrew Green	Faithful & Gould
Jim Baker	Forge Company
Michael Martin	Fusion Building Systems (UK) Ltd
Clive Clowes	Housing Corporation
Karin Stockrel	Housing Corporation
Iwan Williams	Hyde Housing Association
Wei Pan	Loughborough University
Chris Crowley	MACE
Jeanette Kenyon	MACE
Dickon Robinson	Manhattan Loft Company
John Slaughter	HBF
Mehban Chowdery	NHBC
Neil Smith	NHBC
Mark Cousens	Office of the Deputy Prime Minister
Canda Smith	Office of the Deputy Prime Minister
Graham Bettam	Prime Focus Housing Association
Rick Burgess	PRP Architects
Barry Munday	PRP Architects
Nigel Smith	Redrow
Clive Parry	Redrow
Alex Smith	Rollalong
Mike Kay	South Somerset Homes
Dawn Smart	Southern Housing Group
Steven Hicks	Steel Construction Institute
Ross Peedle	Stewart Milne
Stewart Dalgarno	Stewart Milne
Roger McAnnoy	Taylor Woodrow
Bryan Woodley	UK Timber Frame Association
Chris Woods	Wates
Carl Nelson	Zurich Building Services

Our further consultation

Government bodies	Provided expertise on the policy context and related initiatives
■ Department of Trade and Industry	
■ English Partnerships	
■ Housing Corporation	
■ Office of the Deputy Prime Minister	
Registered Social Landlords	Close collaboration with Registered Social Landlords provided detailed project plans from completed and current affordable housing developments and an overview of strategic activities from a range of completed and current schemes
■ Black Country Housing and Community Services Group	
■ Circle Anglia Housing Association	
■ Guinness Trust	
■ Prime Focus Housing Association	
■ South Somerset Homes	
■ Southern Housing Group	
Other industry stakeholders	Liaison with industry provided up to date information in matters such as price, activities sequencing, duration and resource allocation
■ Advanced Panel Systems	
■ Calfordseaden	
■ Design for Homes	
■ Elliott Group Ltd	
■ Faithful & Gould	
■ Flahive Brickwork	
■ Fusion	
■ Gardiner & Theobald	
■ IDOX Leadership Network	
■ Linden Homes	
■ Loughborough University	
■ MACE	
■ Marlborough Brickwork	
■ Modern Masonry Alliance	
■ PRP	
■ Space4	
■ Wave Homes	