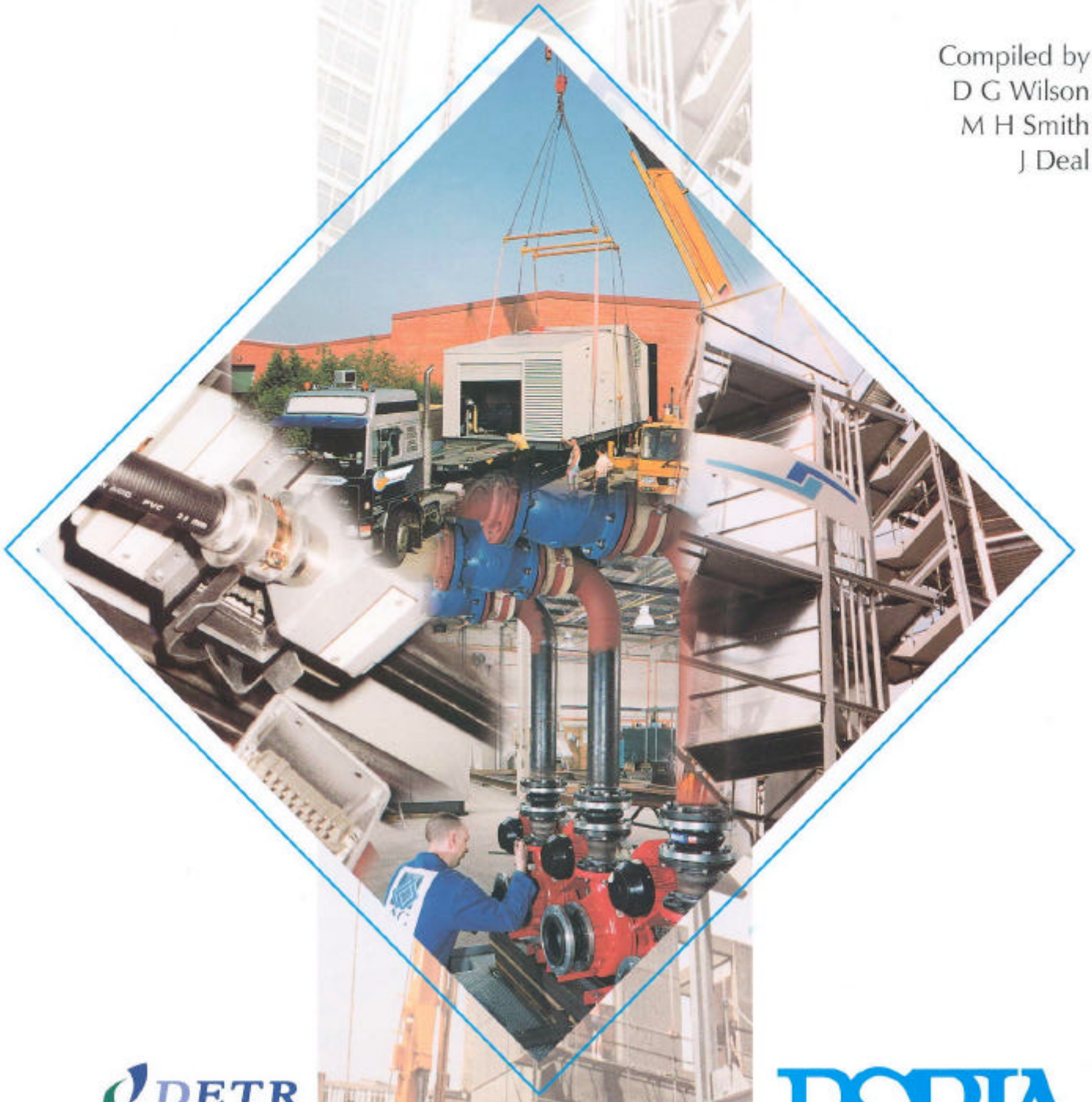
Advanced Construction Techniques ACT 1/99

PREFABRICATION AND PREASSEMBLY

– applying the techniques to building engineering services

Compiled by
D G Wilson
M H Smith
J Deal



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ACKNOWLEDGEMENTS

BSRIA would like to thank the following sponsors for their contribution which has led to the production of this publication. This is the first in a series entitled Advanced Construction Techniques.

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The research project was undertaken under the guidance of a project steering group drawn from industry representatives and BSRIA staff. The Steering Group contributors were:

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The initial BSRIA project team consisted of Greg Hayden and Glenn Hawkins. The final 18 months of the project were completed by David Wilson, Mike Smith and John Deal. The principal site works and observations were performed by David Wilson.

Every opportunity has been taken to incorporate the views of the editorial panel, but final editorial control of this document rests with BSRIA.

EXECUTIVE SUMMARY

The BSRIA report TN 14/97, *Improving M&E Site Productivity* recommended that prefabrication and preassembly should be thoroughly evaluated as one means of enhancing productivity through a change in construction philosophy [Ref 1]. This report contains the findings of such an evaluation - a research project that set out to establish how prefabrication and preassembly could be successfully applied to M&E services to produce more economic installations.

In addition to improvements in productivity, the use of prefabrication and preassembly produces many more benefits for the client and the entire construction team. These benefits include:

- cost savings at every level of the supply chain, typically in excess of 10%
- faster return on investment for the client
- considerably reduced programme times
- improved site management and activities (less labour and materials handling)
- savings in space allocated to services
- improved quality control
- fostering of team working and manufacturing ethos.

Prefabrication and preassembly can be widely applied to building services. Proven applications currently include:

- prefabricated pipework for repetitive application (eg horizontal distribution)
- prefabricated services vertical risers (can include building elements eg staging)
- prefabricated pipework and cabling for complex installations (eg plant rooms)
- preassembled or modular buildings, including services installed in the factory
- preassembled plant rooms, eg boilers, chillers, pumps, switchgear, air handling etc.
- preassembled room terminal units, including all controls and commission elements
- modular electrical wiring, eg lighting installations.

To ensure success, many factors must be considered. The ten most important are:

1. The right motivation and commitment from the whole team including provision of accurate and timely information.
2. Design that is specific to off-site manufacturing.
3. Exploitation of the potential for repeatability and standardisation of components.
4. Procurement strategies that clearly identify suppliers with the right capability, competence and capacity.
5. Tender procedures that allow sufficient design time.
6. Tough quality control procedures.

7. Well managed delivery phasing and site handling.
8. Adequate training of the tradespeople involved, especially those handling, positioning and erecting the finished prefabricated and preassembled products.
9. A detailed approach to commissioning procedures, including off-site functional testing and interaction with the site-installed elements.
10. Exploitation of the shortened M&E programme times, ie earlier start by other trades.

There is considerable potential in further use of prefabrication and preassembly. Some of the issues still to be addressed include:

- overcoming barriers put up by those who are unwilling to innovate
- the need for better site management and the co-ordination of all trades
- better use of IT systems for cad, co-ordination, materials take-off and conveying information to the tradespeople
- provision of training and equipment to tradespeople
- cost of investment in production facilities
- encouraging increased competition and supplier capability.

This report is in three parts. The first part details comparisons with traditional approaches, gives information on the critical success factors, provides a range of visual aids to follow and makes best practice recommendations.

The second part consists of nine detailed, practical case studies undertaken as part of the project. Each case study demonstrates a range of quantifiable benefits, discusses how they were achieved and provides comment on where further improvement might be gained.

The third part contains background information regarding other literature and the research methodology used to quantify productivity improvements.

The work has made some use of the methods developed by BSRIA to quantify productivity. As with the previous report, the sample size is very limited and therefore, the results indicate only what has been achieved in these cases; for other projects the results will be different.

Where productivity measurements have been undertaken, measured improvements through the use of prefabrication and preassembly exceeded 30%. Where cost data was available, the savings, compared with a traditional approach, ranged from 15% to 50%. Great care has been taken to ensure comparisons are valid, with all the many contributory factors such as planning and management accounted for in addition to the mechanistic and straightforward measurement of tasks and time.

In conclusion:

- All the projects studied provided considerable benefits for the participants.
- The application of prefabrication and preassembly did not seem to cause undue problems.
- To gain the maximum benefit from employing prefabrication and preassembly requires the right motivation and support from day one.
- Virtually all installations of building services can benefit from the use of prefabrication and preassembly.
- There are considerable opportunities for companies who are willing to invest in developing prefabrication capabilities and expertise.

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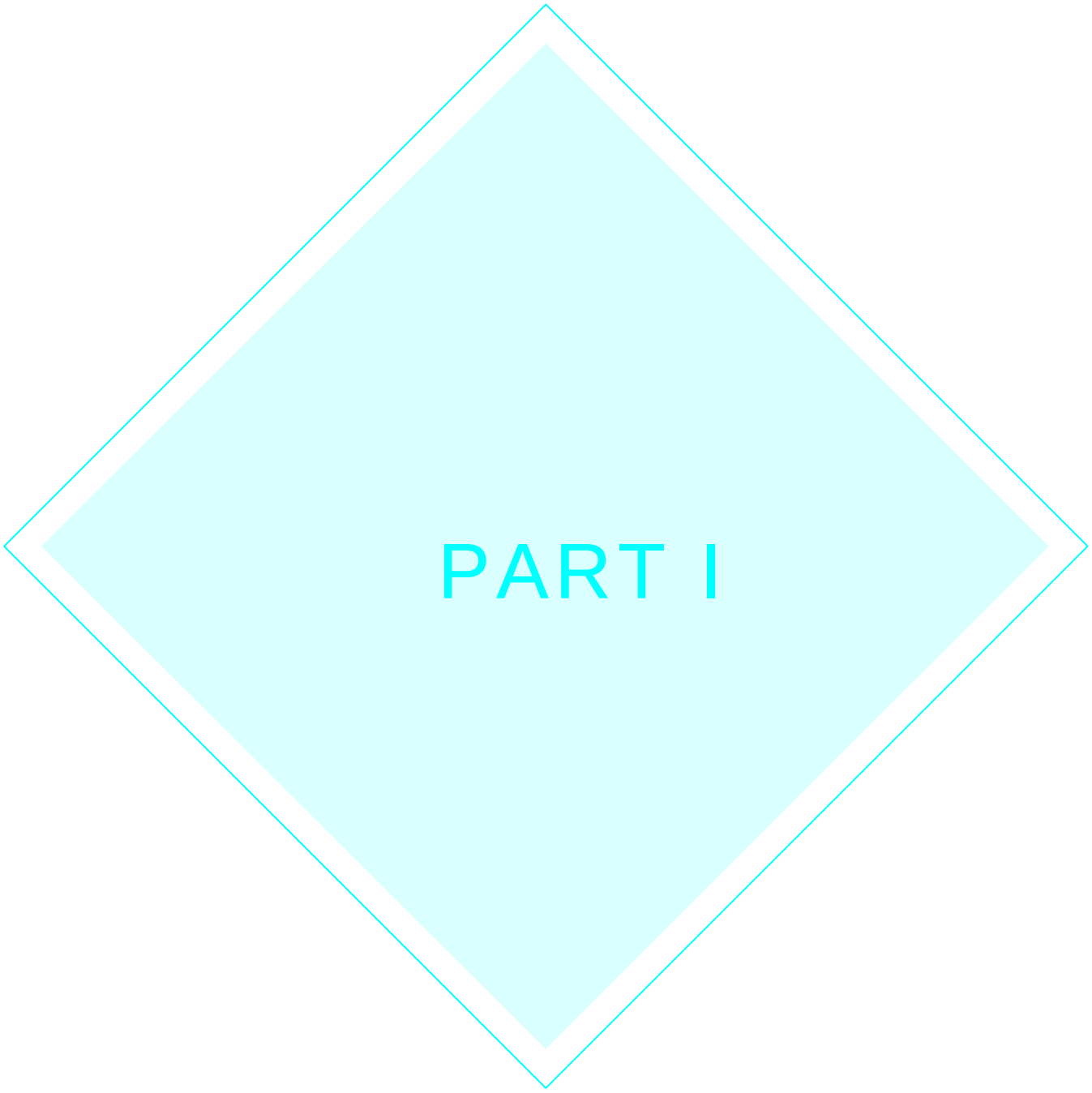
PART III

PREFABRICATION AND PREASSEMBLY



1 INTRODUCTION

The UK construction industry is under continual pressure to raise productivity, reduce costs and improve quality. The need to deliver what the client demands at the right time, to the appropriate quality and at an affordable cost barely warrants repeating here - these needs are the drivers of change in the industry.

This report analyses prefabrication and preassembly in the building services sector, with the objectives of:

- producing guidance for building services engineers, project managers and clients that will explain how prefabrication and preassembly of building services can produce more economic installations
- producing costed examples of conventional and prefabricated/ preassembled solutions.

It examines how the various techniques developed in response to the time, cost and quality issues could be applied more widely to benefit all those involved. Comparisons have been made between prefabrication and traditional methods of installation and the impact of prefabricated and preassembled solutions is considered. Conclusions are drawn and best practice recommendations for prefabrication and preassembly are made.

The report has been produced with the help and encouragement of a number of industry sponsors, listed separately, together with the financial support of The Department of Environment, Transport and the Regions under the Partners in Technology programme.

1.1 BACKGROUND

Against the background of the Latham report - *Constructing the Team* [Ref 2] which examined all aspects of the construction industry and the need to change, many initiatives have been taken. The overriding need to satisfy clients in the time, cost and quality arena has produced a wealth of information to help achieve these objectives.

To help the various initiatives underway in industry, encouragement from UK Government is vital. This is evident in such programmes as the CMR-Link (Construction, Maintenance and Refurbishment programme) with themes of ‘Construction as a Manufacturing Process’ and ‘Customised Solutions from Standardised Components’ signposting the way ahead.

Looking further ahead, the Technology Foresight programme provides the Construction sector with far reaching ideas for the future shape of the industry. This will be covered in more detail later in this report.

The BSRIA report TN 14/97 *Improving M&E Site Productivity* [Ref 1] showed that average productivity on UK construction projects was 37% of observed best practice and that different components, systems and procedures could be employed to increase project performance.

A key recommendation of this report was that a construction philosophy that minimises site activities should be adopted. Further, it recommended that prefabrication and preassembly should be thoroughly evaluated.

To assist the industry in embracing prefabrication and preassembly, BSRIA undertook an investigative study on UK construction projects to identify opportunities in the building services sector and to quantify the benefits, in terms of productivity, cost and quality, when compared to traditional site installation practice.

A comprehensive review of literature on this subject was also undertaken as part of the study.

1.2 DEFINITIONS

This report addresses the need to minimise site activities by employing prefabrication and preassembly where applicable. In the context of this report the following definitions have been applied:

Prefabrication
'The manufacture of component parts of a building and its services prior to their assembly on-site'

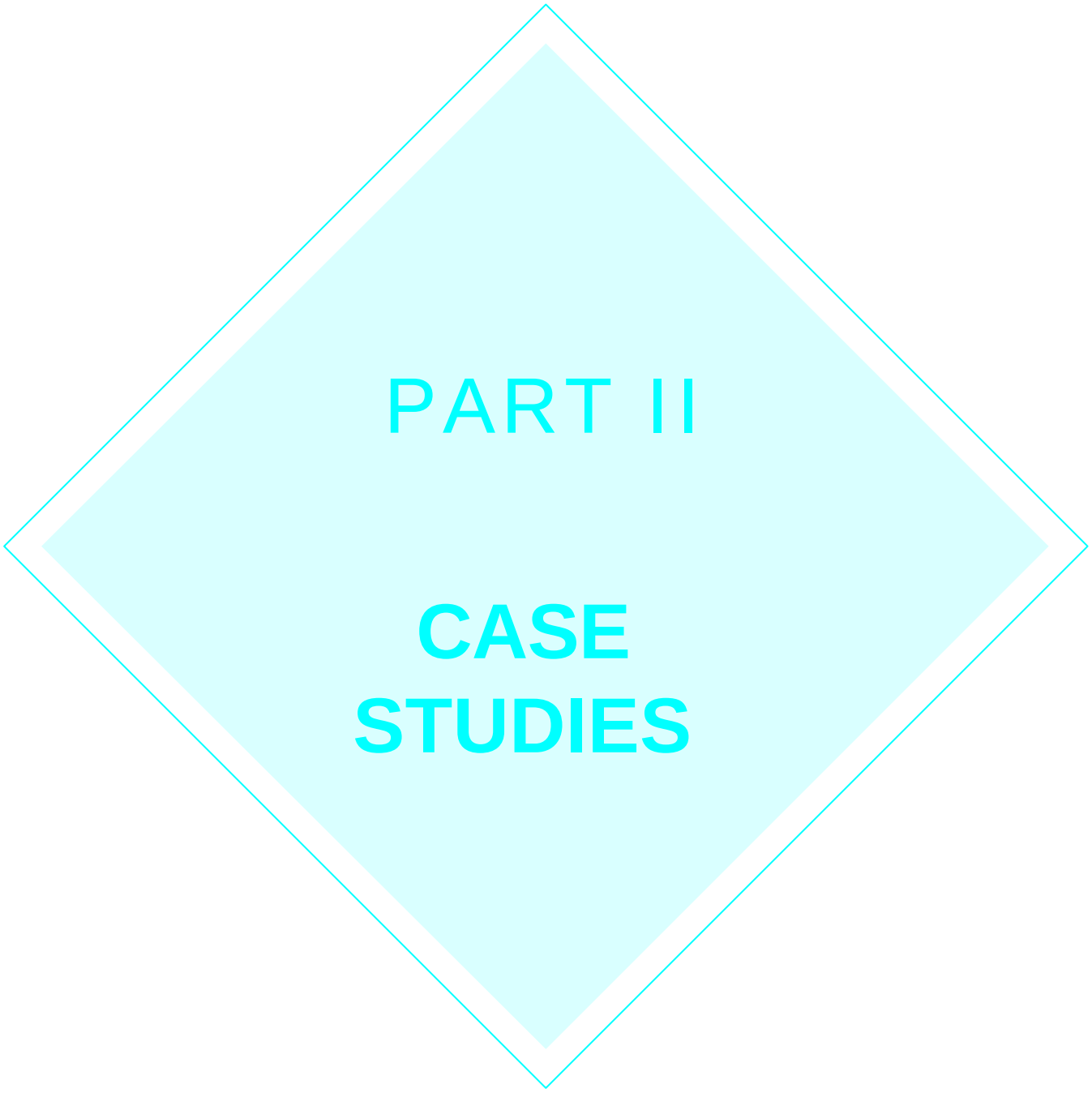
Preassembly
'The manufacture and assembly of a complex unit comprising several components prior to the unit's installation on-site'

Prefabrication would include parts of horizontal and vertical distribution systems, plant room piping arrangements and wiring looms. The key concept is that of adding value to relatively simple, low-intrinsic-value materials and sub-components, eg pipe stock, valves, hangers, supports, cable etc.

Preassembly would include modular buildings, plant rooms and terminal unit assemblies and may involve functional testing off-site. The key concept is that of combining several high-intrinsic-value components into a finished entity (which may include the fabrication of connecting pipework or cabling or decorative finishing) so that upon delivery to site, only positioning and connection to relevant supplies/services is necessary before putting into use, with appropriate site commissioning where necessary.

Elements of prefabrication could be incorporated in preassembly. Also, preassembly is likely to involve specialist subcontractors, eg to provide controls for modular plant rooms.

PREFABRICATION AND PREASSEMBLY



PART II

CASE STUDIES

INTRODUCTION TO CASE STUDIES

This section of the report consists of nine detailed, practical case studies undertaken as part of the project. Each case study demonstrates a range of quantifiable benefits, discusses how they were achieved and provides comment on where further improvements might be gained.

The case studies were selected to provide a variety of prefabricated and preassembled examples demonstrating differing reasons for the initial selection of a prefabricated and preassembled approach. The case studies have been divided into three separate types:

- detailed site monitoring
- overview of an individual project
- company approach to prefabrication and preassembly.

Case studies A, B and C involved detailed, measured observations both in the factory and on-site using the same methodology as the BSRIA report TN14/97 *Improving M&E Site Productivity* [Ref 1]. This allowed a direct comparison between the overall and task productivity of traditional UK and overseas installations against the productivity achieved using prefabrication and preassembly. Case studies D, E and F provide more of a general overview of an individual project and case studies G, H and I describe the approach taken by individual companies in their use of prefabrication and preassembly.

The following case studies were investigated during the research period:

- Case study A - 4-pipe fan coil distribution pipework
- Case study B - Prefabricated boiler room pipework
- Case study C - Preassembled plant modules
- Case study D - Preassembled AHUs and boiler module
- Case study E - Plastic pipe
- Case study F - Preassembly of electrical systems
- Case study G - Modular approach for McDonald’s restaurants
- Case study H - In-house prefabrication
- Case study I - Teamwork and partnering concepts.

A detailed definition of productivity and the methodology used for the productivity analysis can be found in Part III. The same approach towards productivity measurements has been adopted for the prefabrication case studies as the previous investigation into site productivity TN14/97 *Improving M&E Site Productivity* [Ref 1].

A - 4-pipe fan coil pipework

To minimise programme time by prefabrication of repetitive element	*This project used a prefabricated 4-pipe fan coil distribution pipework assembly for an office development. The driving force for deciding to prefabricate was the very repetitious nature of the installation as the building was three floors high with all floors identical.*

B - Prefabricated boiler room pipework

To minimise programme time (client driven) and to cater for space constraints	*This project used prefabricated boiler plant room pipework sections for three boiler rooms in a large commercial building. Every boiler room was slightly different. The driving force for selecting prefabrication was the short programme period, at the client's request. The prefabricated solution's tender price was approximately 15% less than the traditional installation, used in three further boiler rooms on the same site.*

C - Preassembled plant modules

Business continuity	*This project involved the refurbishment of a semi-occupied office block. The project involved the preassembly of seven modules including four roof top AHUs, chilled water pump room and two chiller plant rooms. The driving force for electing to preassemble the plant rooms rather than to install them traditionally was that off-site manufacture would result in minimal disruption to the building's occupants during the refurbishment work therefore maintaining business continuity.*

D - Preassembled AHUs and boiler module

To ease site logistics problems through the use of preassembled modules, eg site storage for materials	*This project involved the preassembly of three bespoke air handling units and a boiler plant room for a speculative office development. The driving force for choosing to preassemble the plant rooms was a 30% saving in roof area, a reduction in on-site material storage and site labour and increased quality.*

E - Plastic pipe

To minimise programme time (client request) and reduce costs	*This project involved the installation of plastic cold water distribution pipework to replace corroded galvanised pipework. The driving force to use plastic pipework was the very short programme period and the ease of installation. In addition, there was a 30% cost reduction.*

F - Preassembly of electrical systems

To reduce site installation time	*Case study F describes the application of preassembled electrical systems to ease site installation. It demonstrates the advantages of these systems and potential areas of adoption. The driving force for the adoption of preassembled electrical systems was improved safety and reduced site installation time.*

G - Modular approach for McDonald's restaurants

Return on investment	*This case study describes the approach taken by McDonald's Restaurants to modularise the construction of their restaurants and reduce their building services costs by 50% in 5 years. The driving force for McDonald's to use modularisation was faster construction time resulting in a faster return on their investment.*

H - In-house prefabrication

Construction as a manufacturing process	*Case study H describes the approach taken by two UK construction companies to develop their own in-house prefabrication facilities. It describes the approach adopted to move from standard construction activities to a manufacturing environment. The driving force for developing in-house prefabrication facilities was to improve quality and reduce lead-in time.*

I - Teamwork and partnering concepts

(under traditional contract)	*Case study I describes the approach taken by a project team to resolve the mutual problems of access to installable areas on risers. It demonstrates the advantage of the adoption of prefabrication under a traditional contract. The driving force to use prefabrication was the need to reduce conflict and delays.*

Critical success factors as shown by the case studies

Critical success factor		Case study								
No.	Description	A	B	C	D	E	F	G	H	I
1	Appropriate site management	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	Appropriate use of skille labour	✓					✓	✓	✓	
3	Quality control	✓		✓	✓	✓	✓	✓	✓	✓
4	Standardisation of components	✓					✓	✓	✓	✓
5	Co-ordination of design specific to off-site manufacture	✓	✓	✓	✓		✓	✓		✓
6	Factory/contractor design capability	✓	✓	✓	✓		✓	✓	✓	✓
7	Design for repeatability and innovation	✓					✓	✓		✓
8	Manufacturer competence	✓	✓	✓	✓		✓	✓	✓	✓
9	Manufacturer quality control	✓		✓	✓		✓	✓	✓	✓
10	Enough time for detailed design and specification				✓					
11	Partnering contract form				✓					✓
12	Correct delivery phasing/scheduling	✓	✓	✓	✓		✓	✓	✓	✓
13	Off-site supervision/inspections		✓	✓	✓		✓	✓		
14	Supply chain management				✓			✓		
15	Training labour in innovative methods					✓		✓	✓	
16	Faster on-site production	✓	✓	✓	✓	✓	✓	✓	✓	✓
17	Reduction in materials delivery and handling	✓	✓	✓	✓	✓	✓	✓	✓	✓
18	Interaction between preassembled and site erected systems (flushing and cleaning)	✓		✓	✓					
19	Off-site functional proving			✓	✓		✓	✓		✓
20	Co-ordination with site erected systems (design performance)			✓	✓					

CASE STUDY A - 4-PIPE FAN COIL DISTRIBUTION PIPEWORK

BENEFITS TO CASE STUDY A FROM THE USE OF PREFABRICATION

- *Substantial improvement in overall and task productivity*
- *Site activities minimised due to off-site manufacture ie reduced deliveries, material handling, site storage space, preparation area, fewer operatives on-site, etc.*
- *Minimised on-site time due to speed of installation*

KEY LEARNING POINTS

- *Good communication between all trades is essential*
- *Care must be taken to prevent damage to modules during transportation and lifting*
- *Good house keeping is essential if productivity is to be maximised*
- *Improved use of IT would aid material take-off*
- *Investigate the potential for a common building services support system*

CASE STUDY CHARACTERISTICS

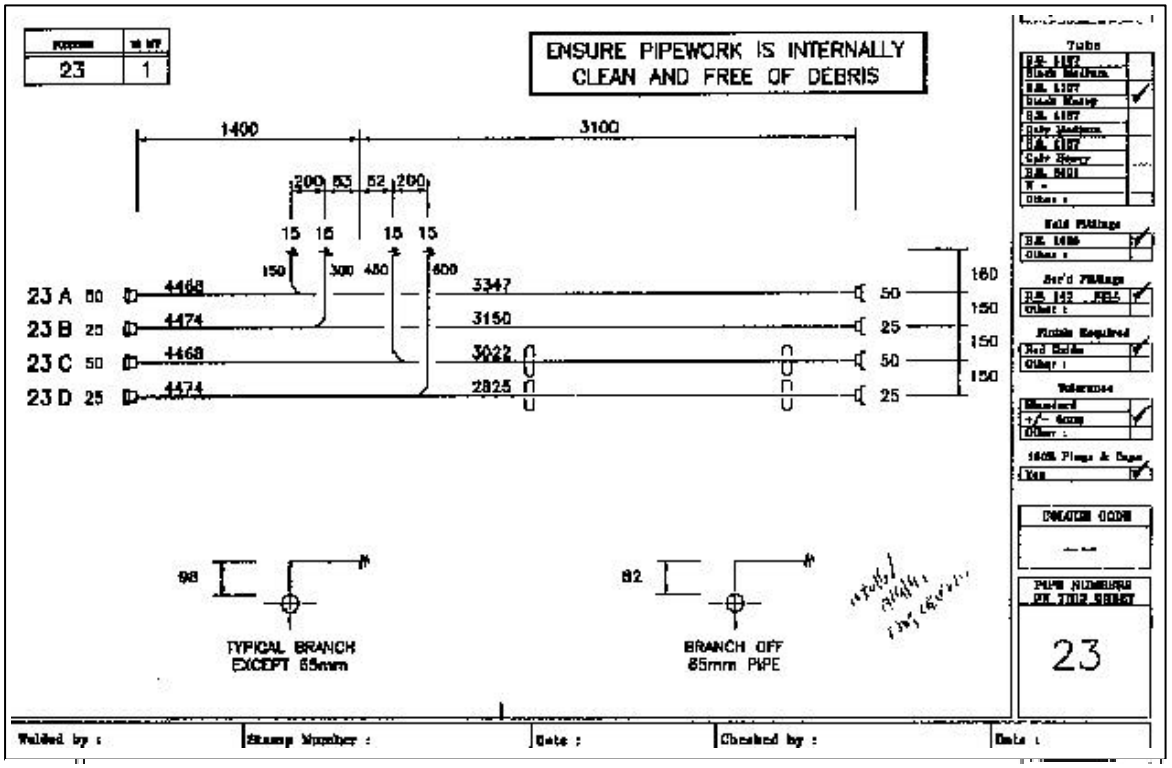
The project involved the construction of two office buildings. Building I had a lettable floor area of 4371 m^2 and Building II had a lettable floor of 6368m^2. Both buildings had three floors. The first building was a total fit-out and the second building was shell and core only. All floors were above ground. Air handling, chiller and boiler plant were located on the roof of each building.

The construction-site was located in an urban location. There was a single vehicular access point at the back of the site. The prefabrication facility was located in an industrial estate approximately 500 metres from the site. There was a railway line running behind the rear of the site.

The approximate total construction costs for both buildings was £12 million. The value of the total mechanical and the electrical services was £2.1 million. Building I mechanical services were worth £1 million and the electrical services were worth £0.4 million. Building II mechanical services were worth £0.5 million and the electrical services were worth £0.2 million.

Observations were carried out on the prefabrication and subsequent site installation of the heating and chilled water horizontal pipework to the fan coil units for Building I. The drawing below illustrates the typical layout for a fan coil pipework module.

Figure A - 1
Four pipe fan coil unit module



FINDINGS FROM THE OBSERVATIONS

The overall productivity and task productivity are shown in Figure A - 2 and Figure A - 3 and the data in Table A - 1. These compare the prefabrication productivity observed on this site with the average productivity observed from the four UK sites and three overseas sites monitored in BSRIA's *Improving M&E Site Productivity* [Ref 1] report. It can be seen that the overall and task average productivity observed on the prefabrication project is better than the overall and task productivity observed on the traditionally installed UK and overseas projects.

Figure A - 2
Overall productivity for hot and chilled pipework