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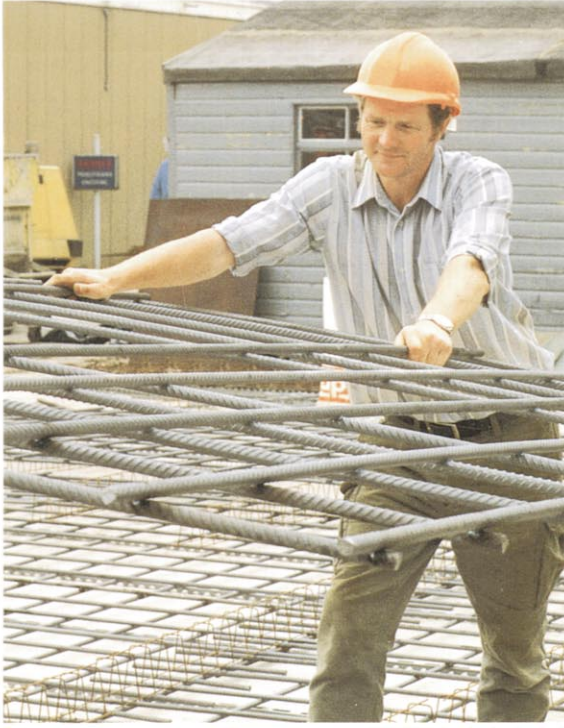
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ECONOMIC ASSEMBLY OF REINFORCEMENT

A review of prefabricated reinforcement and how it results in rapid on-site installation of reinforcement.

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and

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FOREWORD

This publication was commissioned by the Reinforced Concrete Council which was set up to promote better knowledge and understanding of reinforced concrete design and building technology.

Its members are Sheerness Steel plc, Allied Steel and Wire Limited, and the British Reinforcement Manufacturers Association, representing the major suppliers of reinforcing steel in the UK, and the British Cement Association, representing the major manufacturers of Portland cement in the UK.

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PREFACE

There has always been pressure to reduce the time and cost of construction works. However prefabrication – a common way to increase efficiency – has only recently been applied to reinforcement for concrete in framed buildings.

Prefabricated reinforcement and fabric reinforcement using high yield bars/wires welded into mats, enable rapid site installation of reinforcement. Fixing times are typically only a quarter of those needed for loose bars.

Many construction activities are potentially dangerous so care is needed at all times. Current legislation requires all persons to consider the effects of their actions or lack of action on the health and safety of themselves and others. Advice on safety legislation may be obtained from any of the offices of the Health and Safety Executive.

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INTRODUCTION

Prefabricated reinforcement has been used in concrete construction for more than 50 years, both in the UK and abroad. Worldwide, over 15 million tonnes of welded reinforcement mats, commonly known as 'fabric reinforcement', and bar mats, are being used annually in widely varying building and civil engineering projects.

Fabric reinforcement's share of the German reinforcement market is approximately 45%, which amounted to about 1.5 million tonnes in 1990; but it has made only a 15% penetration into the UK reinforcement market.

This difference in market share is largely due to a UK preference for the traditional practice of using loose bar reinforcement. Here, prefabricated reinforcement has been used only to a limited extent and its potential for saving both labour and time remains largely untapped.

This publication reviews the benefits of prefabricated reinforcement, in the form of both loose bars and fabric mats, with emphasis on the use of fabrics. It outlines the recommended practice for the economic design and detailing of prefabricated reinforcement for suspended slabs, beams, columns, and walls. It also reports the speed trials undertaken to compare the installation times for loose bar and fabric mats for a solid slab, a beam, and a column. Two case studies are included.

BENEFITS OF PREFABRICATED REINFORCEMENT

The main reason for specifying prefabricated reinforcement is the shorter construction time. However, prefabrication of reinforcement requires commitment at the design stage if the benefits of faster construction and earlier completion are to be fully exploited.

Prefabrication can lead to simplified reinforcement drawings, which are cheaper to produce, simpler to check and less likely to be misinterpreted on site. It also results in a more uniform work load for fixing crews and less congestion at the workface, allowing better access and shorter fixing times.

For loose bar reinforcement, the fixing price varies according to bar size and bar length, plus additional charges for fixtures, access, degree of difficulty and reinforcement congestion. Smaller diameter bars cost more per tonne to fix. Shorter bar lengths mean more material to locate and fix in a given area. Difficult access, such as in deep beams and congested areas, slows productivity and attracts higher fixing rates. The variation in fixing costs is considerably reduced with prefabricated reinforcement.

Extra cost is also incurred with loose bars by the need to locate and clean them on a muddy site and to arrange their delivery to suit the construction sequence.

Prefabricated reinforcement can either be manufactured under factory conditions, (Figure 1), or on site away from the workface. It can take the following forms:

- Fabric reinforcement, purpose-made to match most alternative loose bar layouts, fabricated in accordance with BS 4466(l).
- Fabric reinforcement and cut and bent loose bars prefabricated into cages prior to fixing.
- Cut and bent loose bars prefabricated prior to installation.

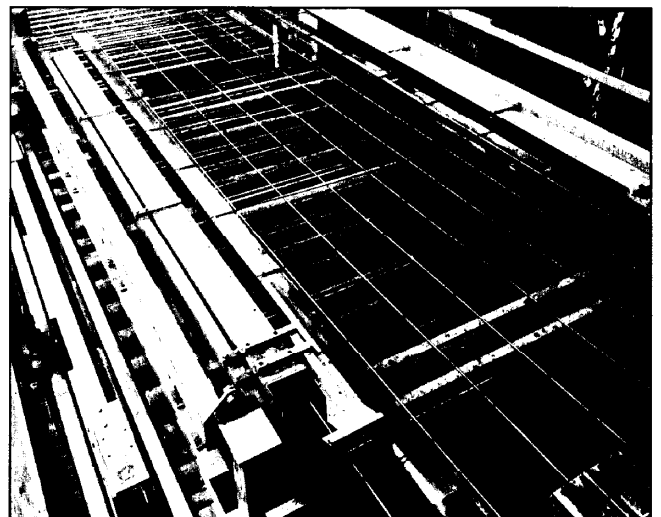


Figure 1: Reinforcement being produced in a factory.

Although prefabrication will generally require some modification of traditional reinforcement detailing, the designer still has the freedom to nominate the bar size and the spacing to suit a particular design requirement. This is best achieved in collaboration with the reinforcement fabricator.

WELDED REINFORCEMENT MATS

Welded reinforcement mats are the most commonly used form of prefabricated reinforcement and are particularly suitable for flat slab construction. The tonnage fixed per man day can be up to nine times that for loose bars, as demonstrated by the time trials described in the appendix on page 13. This more than justifies the small extra cost of fabrication.

Welded reinforcement mats are produced either by electrical-resistance welding, or by electric arc welding and can be supplied either machine or manually welded. It is generally more cost-effective for reinforcement to be machine welded because of the lower production costs and faster throughput of material.

Welded reinforcement mats can be detailed as either flat or bent sheets, depending on particular job requirements. They are suitable for flat slabs, raft foundations, pile caps, retaining walls, shear walls, and beams and columns – in fact, most applications where loose bar reinforcement is suitable. Typical shape code detailing for welded reinforcement mats is the same as for loose bar reinforcement^(1,2), (Figure 2).

Further information on fabric reinforcement mats may be obtained from members of the British Reinforcement Manufacturers Association.

There are three categories of welded reinforcement mats:

- BS designated fabric mats, where the wire and mesh arrangement can be defined by an identifiable fabric reference.

Scheduled fabric mats, with a regular wire and mesh arrangement that can be defined by specifying the size and spacing in each direction.

- Detailed fabric mats, with variable spacing, size and length of wire.

Welded reinforcement mats made to BS 4483⁽³⁾, are manufactured either from cold-reduced steel wire to BS 4482⁽⁴⁾, or from hot-rolled, high-yield steel bars to BS 4449⁽⁵⁾. Each wire intersection is resistance welded using electronically controlled techniques. Fabric with material diameters of up to 12 mm is usually manufactured from steel wire; high yield steel bars are used for larger diameters.

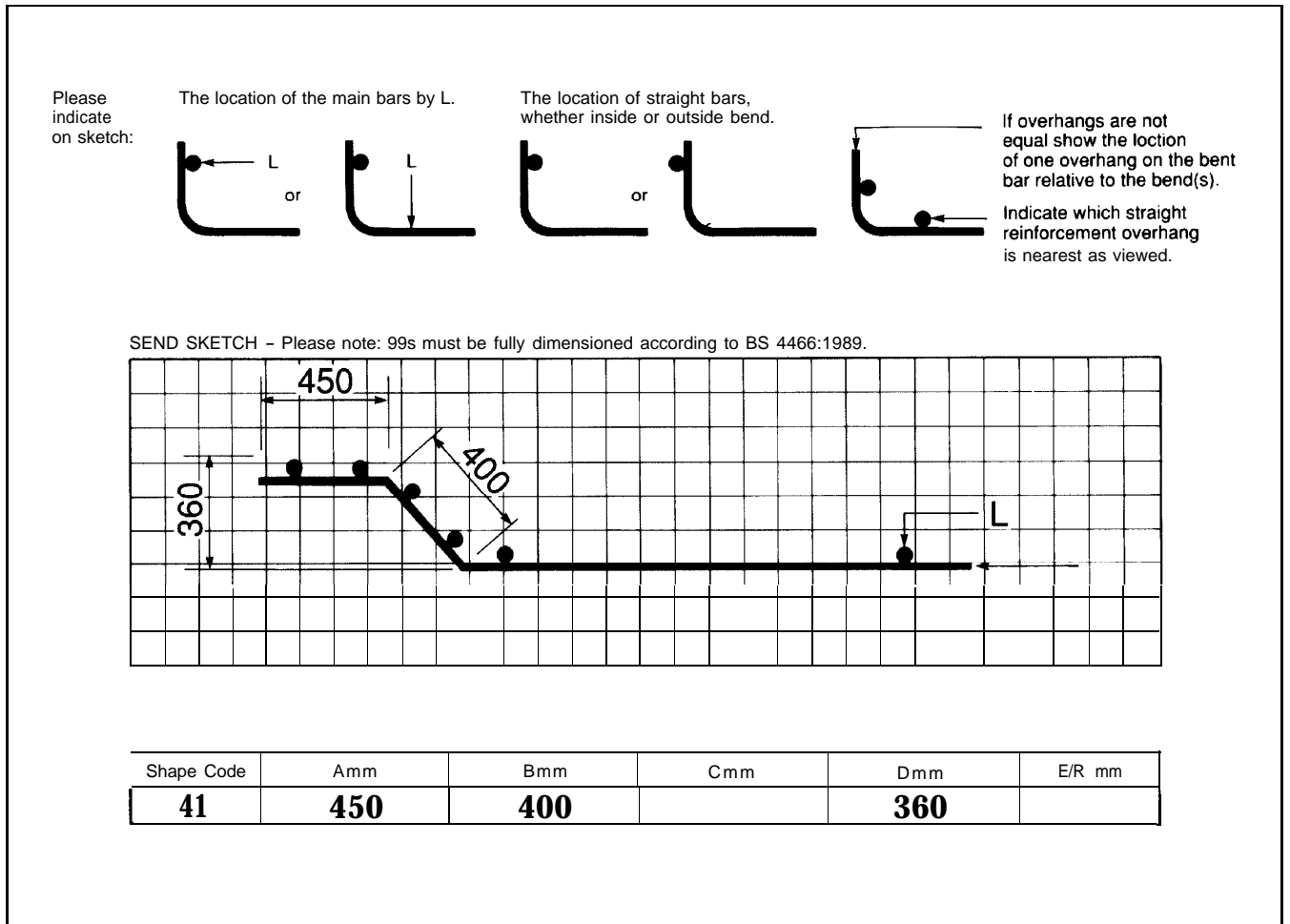


Figure 2: Shape code detailing for fabric reinforcement (based on reference 2).

BS designated fabric mats

BS designated fabric mats are standard welded reinforcement mats and are scheduled very simply by reference to the fabric type, sheet dimensions, and shape code.

Four standard types of BS designated fabric mats are widely available, with wire sizes mainly between 5 and 12 mm and a standard sheet size of 4.8 x 2.4 m, (see Table 1 below).

The four standard types are:

Type A: Square mesh fabric. This has wires of the same size and spacing, both longitudinally and transversely. It is used where a slab or wall needs the same area of reinforcement in both directions.

Type B: Structural mesh fabric. This is generally used where the main reinforcement is in one direction and the reinforcement in the other direction is the minimum required by codes of practice.

Type C: Long mesh fabric. This is used in structures where the main reinforcement is in one direction and the reinforcement in the other direction does not have to meet any minimum requirements and serves only to hold the main reinforcement in place.

Type D: Wrapping fabric. This type of BS designated fabric is mainly used in wrapping for fire protection and for links in columns. It is sometimes used as nominal reinforcement in beam cages.

Scheduled fabric mats

Scheduled fabric mats, (Figure 3), are welded reinforcement mats having a regular mesh arrangement in each direction. The full range of bar sizes, up to 20 mm, may be specified for this type of fabric, although machine-made fabric is restricted to bars up to 16 mm in size.

When scheduling, the bar size in each direction is called up, stating the bar number, the spacing, the length, the overhang at each end and any bending details.

Detailed fabric mats

Detailed fabric mats are welded reinforcement mats with no practical limit to the spacing, size and lengths of reinforcement within an individual mat, other than keeping within machine tolerances for diameter and spacing.

The spacing of longitudinal and cross wires can be adjusted to optimize the steel area per metre run. Most combinations of wire size, spacing, and mat width and length can be specified, although manufacturers have preferred dimensions, (Table 2).

A drawing is required for scheduling detailed fabric mats. The schedule will show the bar sizes, the bar length, spacings for each bar and the bar overhang. In addition, dimensions to any stagger must be stated together with any bending details.

A typical example of a schedule for detailed fabric is given in Figure 4 on page 6.

Table 1: Preferred range of BS designated fabric types and stock sheet sizes [based on BS 4483: 1985⁽³⁾].

Fabric reference		Longitudinal wires			Cross wires			Mass kg/m ²
		Nominal wire size mm	Pitch mm	Area mm ² /m	Nominal wire size mm	Pitch mm	Area mm ² /m	
Square mesh	A393	10	200	393	10	200	393	6.16
	A252	8	200	252	a	200	252	3.95
	AI 93	7	200	193	7	200	193	3.02
	AI 42	6	200	142	6	200	142	2.22
	A98	5	200	98	5	200	98	1.54
Structural mesh	81131	12	100	1131	a	200	252	10.9
	B785	10	100	785	a	200	252	a.14
	B503	a	100	503	a	200	252	5.93
	8385	7	100	385	7	200	193	4.53
	B283	6	100	283	7	200	193	3.73
	B196	5	100	196	7	200	193	3.05
Long mesh	C785	10	100	785	6	400	70.8	6.72
	C636	9	100	636	6	400	70.8	5.55
	C503	a	100	503	5	400	49	4.34
	C385	7	100	385	5	400	49	3.41
	C283	6	100	283	5	400	49	2.61
Wrapping mesh	D98	5	200	98	5	200	98	1.54
	D49	2.5	100	49	2.5	100	49	0.77
Stock sheet size	Longitudinal wires Length 4.8 m			Cross wires Width 2.4 m			Sheet area 11.52 m ²	

NOTE: values **are** subject to the tolerances specified in clause 9.

Lapping and types of lap

Anchorage and lap lengths, summarized in Table 3, can be determined using the ultimate anchorage bond values for fabrics given in BS 8110: Part 1⁽⁶⁾. Five types of lap are commonly used for welded reinforcement mats, as shown in Figure 5 on page 7.

Layered lap. This is the arrangement generally adopted, where the fabric mats are laid on top of each other in the lap zone. Congestion of steel in the lap zone can be minimized by arranging the mats so that the bars are placed on top of one another.

Reversed and nested in-plane laps. These maintain the lapped reinforcement in the same plane and are particularly useful in positions of maximum stress. One mat is turned upside down relative to the other and moved sideways slightly so that there are three layers of reinforcement in the lap zone.

Table 3: Tension anchorage and lap length (based on Table 3.29 of BS 8110⁽⁶⁾).

Concrete grade	C25	C30	C35	C40
Grade 460 Deformed type 2 (ribbed) wire BS 4482	40d	37d	34d	32d
Grade 460 (high yield) Deformed type 2 (ribbed) bars	406	37d	34d	32d
Grade 460 Plain round wire	71d	65d	42d	40d

Flying ends lap. This is an in-plane lap where one sheet provides a lap length overhang without any welded intersections. The overhang is the length of the bars projecting beyond the peripheral cross-over points in the sheet.

Edge lap. This is similar to the layered lap but with smaller size longitudinal bars in the lap zone, so that the area of longitudinal reinforcement is substantially uniform throughout.

Not all laps can be used with all types of fabric. Their suitability is shown in Table 4.

Table 4: Suitability of laps for use with various fabrics.

Lap	Fabric		
	Designated	Scheduled	Detailed
Layered	✓	✓	✓
Reversed	✓	✓	✓
Nested	✓	✓	✓
Flying ends		✓	✓
Edge			✓

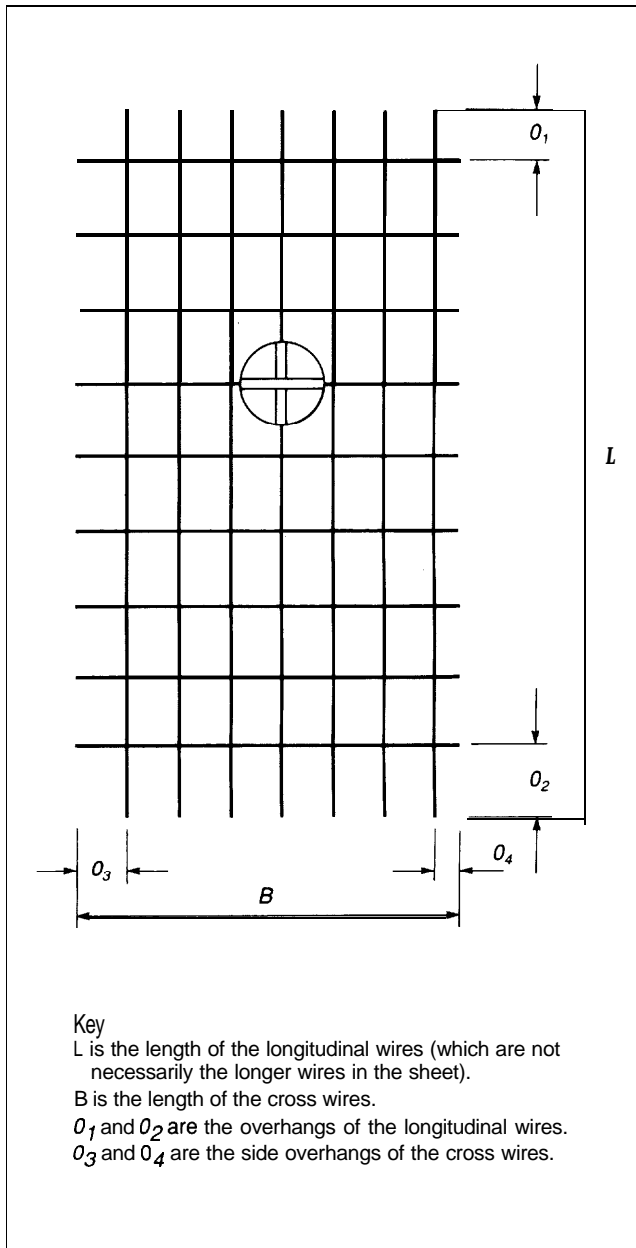


Figure 3: Scheduled fabric (based on BS 4466: 1989).

Table 2: Detailed fabric mats, manufacturers preferred sizes.

Reinforcement	
Wire to BS 4482, bar to BS 4449	
Minimum size	4 mm
Maximum size	16 mm
Sheet length	
Maximum sheet length	12.0 m
(Longer lengths may be considered on application)	
Minimum sheet length	2.0 m
Sheet width	
Maximum sheet width	3.4 m
Minimum sheet width	1.0 m
Wire pitch	
Minimum main wire pitch	50 mm
Minimum cross wire pitch	50 mm
Overhang	
Minimum cross wire overhang	25 mm
Minimum longitudinal wire overhang	25 mm

Two-directional mats were used for the lift shaft walls. Economical prefabrication was achieved, despite the awkward plan area of the building, by keeping the spacing of the main bars constant. For the walls, mats were prefabricated with flying ends to ease congestion and to simplify the construction of the upper lifts.

The contractor estimated that there was a 75% reduction in the fixing time for the basement and lift shaft walls compared with using loose bars, with a reduction in labour costs of around 25% for the entire steel fixing job because the steel fixing gangs were reduced from eight to six in number.

For the floor slabs, single-directional mats with flying ends were cut on site to suit the awkward building shapes. Fabric reinforcement undoubtedly helped the contractor to achieve greater speed of construction and enabled the frame to be topped out in under 14 weeks. Steel fixing time for floor areas was reduced by 35% compared with the loose bar alternative, fully justifying the decision to adopt fabric reinforcement assemblies.

RCI Limited, Kettering

This is a **£6.5** million, four-storey office building in Kettering, Northants.

The structural consultants specified fabric to help speed the construction cycle. Approximately 70 tonnes of fabric reinforcement for the floor slabs were manufactured by special machine.

Two-directional mats, (Figure 15), were detailed for all slabs, with loose bars specified for the column and beam cages.

The design and build contractors were quick to appreciate the advantages of the fabric reinforcement specified, and the steel fixers on the project confirmed that using purpose-made fabric enabled them to do their job in half the time, with two men rather than three.

The specification of fabric reinforcement ahead of construction enabled production of reinforcement to be planned and co-ordinated efficiently. It also gave the contractor time to familiarize the steel fixing crew with the simplicity of fabric reinforcement before starting work.

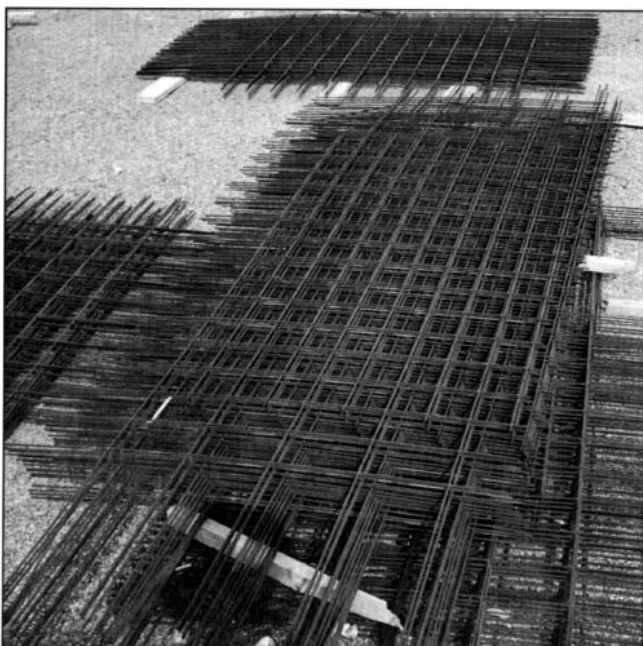


Figure 15: RCI Limited, Kettering: two-directional fabric reinforcement for floor slabs.

CONCLUSION

Prefabricated reinforcement assemblies can be used for all types of structural elements including floors, columns, beams and walls. They offer benefits to the contractor, designer and client, resulting in:

- lower labour intensity;
- faster fixing rate;
- less likelihood of material wastage;
- simplified detailing and easier fixing in most instances;
- improved site planning and organization;
- improved quality from factory-controlled assembly,

When using prefabricated reinforcement, the following points should be taken into account.

- To achieve the best savings, designers should involve fabric manufacturers early in the design process.
- Specifying prefabricated reinforcement at the design stage enables contractors to tender more competitively, allowing the consequent savings in time and cost to be passed on to the client.
- Repetition is essential for economy when designing prefabricated reinforcement; for economic production of non-standard fabrics, a mat size should be repeated at least **20** times.
- The choice between loose bar assemblies, single-directional and two-directional fabric mats depends on the availability of cranes, the amount of reinforcement, the project size and the need for greater speed of construction.

The development of machine-made, tailored fabric reinforcement has created major opportunities for savings in project costs and construction times. The results of the BCA speed trials and similar studies in Germany, and the two case histories reported here, provide compelling evidence of the need for a major change in the specification and detailing of reinforcement for structural concrete.

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