

British Precast Code of Practice for:

THE SAFE STRESSING OF PRESTRESSED CONCRETE PRODUCTS



2014



PREFACE

This Code of Practice brings together the many developments, not only in Health and Safety legislation, but also in best practice within the prestressing industry. It gives a guide to the current best practice, but in an ever-changing situation, can only be totally up-to-date at the time of its publication.

British Precast is committed to achieving a high standard and universal approach to Health and Safety, and part of this is the provision to employees, customers and designers alike of clearly presented information about the systems of work employed.

This Code has been prepared with the assistance of the membership of British Precast and of the Health and Safety Executive (HSE), who have provided invaluable assistance with its development; this is much appreciated.

This edition will be published almost exclusively as a download from the British Precast website, although a number of loose-leaf ring-binder copies will be made available to members of participating companies and individuals, training organisations and the Health and Safety Executive. This Code will be updated online.

Stressing of prestressed concrete is acknowledged to be a potentially high-risk activity, as it involves the use of industrial prestressing equipment that uses hydraulic rams to stretch high-yield wires and strands with forces that can be in excess of 1500 tonnes.

This Code of Practice has been produced for the following purposes:

1. For safety awareness within the Industry.
2. For planning the production process and equipment required.
3. For training of all personnel involved with stressing operations.
4. The preparation of safe working method statements.

Published and distributed by

British Precast

The Old Rectory

Main Street

Glenfield

Leicester

LE3 8DG

Email: info@britishprecast.org

Web: www.britishprecast.org

First published 2014

A catalogue record for this book is available from the British Library

Every effort has been made to ensure that the statements made and advice given provide a safe and accurate guide; however, no liability or responsibility of any kind (including liability for negligence) can be accepted in this respect by the publishers or the authors

FOREWORD

HSE encourages and welcomes industry codes of practice such as this produced by The British Precast Federation (BPCF), which receive careful consideration and input from key players within the industry who have the health, safety and welfare of those involved in pre-stressing work foremost in their mind.

When a stressing bed system fails deaths and serious injuries are likely to occur. If the work is planned and carried out by competent operatives, using equipment properly maintained and inspected then most accidents can be prevented.

I am pleased to acknowledge the work of the BPCF and those involved in preparing this code of practice. It brings together best practice within the industry and has the interest of those involved in the manufacture of prestressed concrete products at heart. It is only by the industry showing leadership, working in partnership, and taking ownership of the management of risk that improvements will be made, and I commend its use to all concerned.

Philip White

Head of Operational Strategy Division
Health and Safety Executive

Acknowledgements

The members of the Best Practice Task Group have made this publication possible. Whilst many individuals have contributed, the following are amongst those who deserve particular mention:

David Appleton	Laing O'Rourke
Dr Stewart Arnold	HSE
Mark Bradley	Charcon Construction Solutions
Shaun Brown	Charcon Construction Solutions
Roy Butterfield	Creagh Concrete
Stephen Carr	Spiroll
Paul Feely	Creagh Concrete
Gerard Feenan	Charcon Construction Solutions
Frank Howarth	EKC Systems
Barry March	Cemex
Andrew Minson	BPCF
Jonathan O'Coy	FP McCann
Neil Orr	Hanson
Norman Richards	Richards Associates
George Pickard	Litecast
Nigel Roberts (Chair)	Megasteel
Ian Smart	HSE
David Squires	Applied Safety Services
Susan Townsend	Cemex
Mark Wilson	EKC Systems
	HSE, Northern Ireland

Message from the Chairman of the Best Practice Task Group

In response to industry demand, British Precast has adopted an across-the-industry stance to the preparation of this Code of Practice. Members and non-members, together with representatives of the HSE, have joined forces to form the Best Practice Task Group and to prepare this Code in order to promote zero harm in the work place.

Members of the Best Practice Task Group are drawn largely from the prestressed flooring industry; however the Code applies equally to other prestressed products including:

- Floor beams
- Lintels
- Wet-cast slabs
- Bridge beams
- Rail sleepers

The Code covers 'gate to gate' health and safety – from receipt of prestressing wire/strand from the manufacturer to incorporation within the prestressed product.

The design decisions made when establishing new production capacity can have implications on safety, and this Code should be referred to when making such decisions.

Nigel Roberts

Best Practice Task Group

Message from the British Precast Executive Director

This is the first edition of the British Precast *Code of Practice for the safe stressing of prestressed concrete products*. Its publication coincides with the launch of the British Precast Charter through which members pledge to work to the Code whilst undertaking prestressing operations. Under the charter, conformity with this Code is subject to an independent audit system that will commence from November 2014.

We advise all manufacturers involved in prestressing operations to take a detailed look at the content.

Andrew Minson

Executive Director
British Precast

Message from British Precast President

This is a bold initiative towards zero harm in the precast industry and accords with the aims of raising standards in the workplace.

The dangers of the prestressing process should be fully appreciated, and this Code goes a long way towards establishing a safer working environment for all involved in the prestressing operations.

Our special thanks go to the Best Practice Task Group in the preparation of this Code and we welcome the support of all the companies who add their weight behind its introduction.

Andy Dix

President British Precast

Code of practice for: The safe stressing of prestressed concrete products

CONTENTS

See over for detailed contents

0.1 DEFINITIONS	8
0.2 BIBLIOGRAPHY	11
1. INTRODUCTION TO PRESTRESSING IN A FACTORY ENVIRONMENT	13
2. STRESSING PROCESS AND EQUIPMENT	17
3. WIRE AND STRAND	21
4. WIRING UP THE BED	29
5. BARRELS AND WEDGES	31
6. STRESSING	37
7. CONCRETE CASTING	43
8. DE-STRESSING	45
9. REMOVING BARRELS AND WEDGES	47
APPENDIX A TRAINING, CERTIFICATION AND COMPETENCE	49
APPENDIX B NATIONAL TRAINING SCHEME	51
APPENDIX C FACTORY AUDIT FOR SAFE STRESSING	56
APPENDIX D COMPANY SAFETY POLICY	57

DETAILED CONTENTS

0.1 DEFINITIONS

0.2 BIBLIOGRAPHY

1 INTRODUCTION TO PRESTRESSING

- 1.1 Prestressed concrete manufacturing
- 1.2 Prestressed concrete design
- 1.3 Design responsibility
- 1.4 Product type testing
- 1.5 Constituents
- 1.6 Concrete
- 1.7 Prestressing steel
- 1.8 Production of prestressed concrete products

2 STRESSING PROCESS AND EQUIPMENT

- 2.1 Multi-stressing system
- 2.2- Single wire/strand stressing
- 2.3- Maintenance
- 2.4 Mouldage and stressing abutments
 - 2.4.1 Moulds
 - 2.4.2 Abutments
 - 2.4.3-Inspection and maintenance

3 WIRE AND STRAND

- 3.1 Wire
- 3.2 Strand
- 3.3 Purchase orders
- 3.4 Delivery
- 3.5 Offloading and handling
 - 3.5.1 Wire
 - 3.5.2 Strand
- 3.6- Storing wire and strand
 - 3.6.1 Wire
 - 3.6.2 Strand
- 3.7 Stock rotation
- 3.8 Cutting strapping
- 3.9 Dispensing wire and strand
 - 3.9.1 Wire
 - 3.9.2 Damaged or kinked wire
 - 3.9.3 Strand
 - 3.9.4 Hot metal working

4 WIRING UP THE BED

- 4.1 Running wires/strand

- 4.2 Cutting wire/strand
 - 4.2.1 Angle grinders
 - 4.2.2 Bolt croppers

5 BARRELS AND WEDGES

- 5.1 Procurement of stressing components
- 5.2 Storage
- 5.3 Inspection, cleaning and lubrication
- 5.4 Identifying barrels and wedges
 - 5.4.1 Open barrels and wedges
 - 5.4.2 Enclosed barrels and wedges
 - 5.4.3 Wire/strand coupler
 - 5.4.4 Button headings
- 5.5 Fitting the barrels and wedges

6 STRESSING

- 6.1 Methods of stressing
 - 6.1.2 Single wire/strand stressing
 - 6.1.3- Multi wire/strand stressing
- 6.2 Placing safety restraints
- 6.3- Stressing load checks
- 6.4 Guarding
- 6.5 Warning systems
 - 6.5.1 Lights
 - 6.5.2 Sirens
 - 6.5.3 Notices

7 CONCRETE CASTING

- 7.1 Machine casting
- 7.2 Wet casting
- 7.3 Concrete strength

8 DE-STRESSING

- 8.1 Multi-wire/strand de-stressing
- 8.2 Single wire/strand de-stressing
- 8.3 Shock de-stressing

9 REMOVING BARRELS AND WEDGES

APPENDIX A TRAINING, CERTIFICATION AND COMPETENCE

APPENDIX B NATIONAL TRAINING SCHEME

APPENDIX C FACTORY AUDIT FOR SAFE STRESSING

APPENDIX D COMPANY STRESSING POLICY

0.1 DEFINITIONS

Most of the terms used in this document are in common use. However, the following definitions are intended to remove any ambiguity:

Abutment: Fabricated steel assembly at the end of a stressing bed sometimes drilled with holes to suit the wire/strand pattern, which takes the forces from the stressed wire/strand and transfers them into the ground, concrete or steel frame of the mould.

Anchor: See barrel, wedge and button heading.

Appointed Person: The person employed by the 'Company' to have overall control of the stressing operation and to act on behalf of the 'Company'. The Appointed Person must have adequate training and experience to ensure the implementation of a safe system of work.

Barrel: This holds the gripping wedge at the end of the stressing beds. Sometimes referred to as a collar, cone, or a chuck.

Bed Operative: Person directly involved with the preparation, set up, tensioning and de-tensioning, or casting and clearance of product on a casting bed.

Button Heading: Term used to identify an anchor system for wire where the wire is deformed by force to create a rounded end.

Calibration Unit: Laboratory calibrated and certificated load cell and read out used to calibrate the pump and jack system on site.

Calibration Certificate: The certificate supplied with details of the jack/pump load/pressure rate.

Certificated: Having been trained and qualified to fulfil a particular role and holding a valid licence/certificate of training, gained by attending a recognised course of instruction for the task in question.

Company: The manufacturer of precast concrete components and associated items and services.

Competent Person: The person is regarded as competent if they have 'sufficient training and experience or knowledge and other qualities to properly assist the employer to meet his safety obligations'.

Components: Any member, article, or item comprised of precast concrete or ancillary metalwork.

Crane Operator: A competent and trained person responsible for the correct operation of the crane in accordance with the Manufacturer's Operating Instructions, the Safe Working Method Statement and directions from the nominated Slinger/Signaller.

Dead End: The fixed end of the bed opposite to the end used for stressing the wire/strand.

Design Engineer: Professionally qualified person ultimately responsible for the overall design of stressed products and stressing operations.

Designer: The person or persons who produces specifications, estimates, drawings, details, designs or calculations for a particular contract.

Dispenser: For dispensing wire or strand from coil – also known as lobster pot, pod.

Electrical Isolation: Method to isolate equipment from sources of electrical energy once the function is complete.

Extension: Distance identified by the engineer that a wire/strand has to be pulled to achieve the design load.

Ferrule: Thick washer used to spread the load when using button heading.

Flooring: The precast concrete components that form the structural element of a floor and may include associated precast components.

Grip: See barrel and wedge.

Hazardous Area: The area identified as a dangerous area in the vicinity of the bed stressing operations.

Hollowcore: Precast concrete flooring system, which for the purposes of this Code is deemed to include terms such as 'wideslab', 'solid planks' etc.

Live End: The end of the bed at which the wires/strands are stressed.

Manager: The person in charge of the prestressing team, undertaking the work for the Company.

Multi-Stressing: A system to tension multiple wires/strands at the same time by moving the end abutment.

Operatives: All other site personnel involved with the pre-stressing works.

Piab System: As an alternative to hydraulic tension, this system uses a crane to pull the wire/strand and a load cell called a Piab trips the crane at the correct load.

Precast Company: The precast company engaged in the supply and/or manufacture of precast components.

Precast Designer: The designer of the precast components, working for or on behalf of the Company.

Prestressing: The process of inputting stress into a concrete element before ("pre") the concrete is stressed in its service role.

Pre Tensioning: The process of prestressing in which the wire or strand is tensioned before ("pre") the concrete is cast.

Strand Pattern: Correct position identified by the design engineer for the wire/strand to ensure the performance of the slab is achieved normally with the minimum amount of strand and concrete.

Stressing Jack: Sometimes referred to as a stressing gun, this is the unit that tensions the pre-stressing wire/strand individually. Various designs are available and compatibility between the equipment is imperative.

Stressing Operative: Person directly involved in the preparation, set up, tensioning or de-tensioning of stressing operations.

T Beams: A flooring system that uses pre-stressed inverted precast concrete T beams together with block infills.

Tendon: This is a term that commonly refers to both wire and strand.

Tendon Design Load: Load identified by the design engineer to which the wire/strand should be stressed.

UTS: Ultimate Tensile Strength (often referred to as the Breaking Load) of the wire/strand.

Work Area: The area on a site where precast components are manufactured and pre-stressed.

Work at Height: Work where there is a significant risk of injury to persons due to falling.

Working Drawings: The layout drawings, section and details, produced by the Precast Designer and issued for client approval and production purposes.

Wedge: This grips the pre-stressing wire/strand in conjunction with the barrel, sometimes referred to as a Bullet or Carrot.

Please note that where the term 'he' or 'his' is used this should also be taken to include 'she' or 'her' as appropriate.

0.2 BIBLIOGRAPHY

This list is not exhaustive, but provides a helpful pointer to useful publications.

Note: Please ensure that you refer to the latest edition of these references.

Her Majesty's Government

- Health and Safety at Work etc. Act 1974
- The Management of Health and Safety at Work Regulations 1999
- The Work at Height Regulations 2005
- The Health and Safety (First Aid) Regulations 1981
- The Control of Noise at Work Regulations 2005
- The Electricity at Work Regulations 1989
- The Personal Protective Equipment at Work Regulations 1992
- The Provision and Use of Work Equipment Regulations 1998
- The Lifting Operations and Lifting Equipment Regulations 1998
- The Manual Handling Operations Regulations 1992
- The Control of Substances Hazardous to Health Regulations 2002
- The Construction (Design and Management) Regulations 2007
- The Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 1995
- The Control of Vibration at Work Regulations 2005

Health and Safety Executive

- GS 6 *Avoidance of danger from overhead electrical lines* 1997

British Standards Institution

British Standards and other guidance notes are issued on a continuing basis and users of this Code of Practice should acquaint themselves with the latest updates and revisions.

- BS 6896 *High tensile steel wire and strand for the prestressing of concrete – Specification*
- BS 5975 *Code of Practice for falsework*
- BS 7121 *Code of Practice for safe use of cranes – Parts 1, 2, 3 and 5.*
- BS 8110 *Structural use of concrete*
Part 1: *Code of Practice for design and construction*
- BS EN 1992–1–1 *Design of concrete structures*
- BS EN 818–4 *Guidance for the purchaser and user of mechanically assembled slings*

1 INTRODUCTION TO PRESTRESSING IN A FACTORY ENVIRONMENT

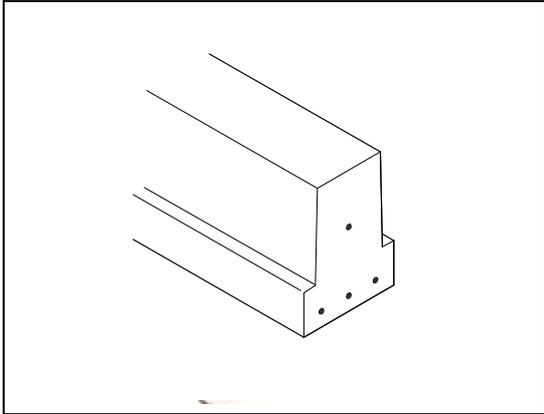


Figure 1.1
T beam unit for beam and block flooring.

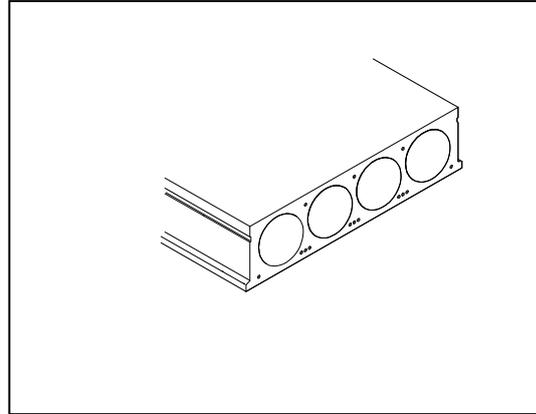


Figure 1.2
Hollowcore flooring unit

Prestressing is a highly efficient method of manufacturing reinforced precast concrete structural products and is recognized as a modern method of construction. It is most often used in the manufacture of products offsite in factory-controlled conditions, to strict design criteria. The design principle behind prestressed concrete is that, by inducing compressive and bending stresses through high-strength steel wires or strands in a concrete member during or after manufacture, these stresses will approximately balance the tensile and bending stresses imposed in the member during service. This increases the structural efficiency of products. The following section gives a brief introduction to prestressing. In this Code of Practice, particular emphasis is put on areas where special consideration to safety is required.

This Section looks at how the manufacturing and design process are combined in the creation of prestressed structural products.

1.1 Manufacture of prestressed concrete

The manufacturing process has several stages, including:

- Multiple high-yield steel wires or strands are set to a predetermined wire pattern within the concrete section. They may be the sole reinforcement in the section or may be supplemented by normal reinforcement to resist all combinations of load effects.
- The wires/strands are extended to a predetermined load by hydraulic equipment, and the ends are clamped.
- Concrete is poured around the wires/strands, the concrete shape being formed by the mould. For some products the shape of the concrete is achieved by the use of slip form or extrusion casting machines.
- The concrete is allowed to cure in a controlled temperature and humidity environment.
- As the concrete matures it is monitored to ensure sufficient strength development to allow transfer of the prestress.
- The clamped ends are released thereby transferring the prestressing force held in the wires/strands into the concrete member as the extended wires/strands try to return to their original length. The wire/strands are cut at the ends of the elements and a state of equilibrium of internal forces is attained in the section.
- The concrete matures further until the product is deemed ready for incorporation into the structure.

1.2 Prestressed concrete design

To an Engineer responsible for the design of a concrete structure or building element, prestressing refers to the practice of inducing a beneficial stress or load effect into an element or part of the structure to counter the stresses or load effects that occur during the service life of the structure. As a result elements can be made more slender i.e. longer and lighter, providing opportunity for offsite manufacture and savings in cost or programme by prefabrication.

The types of reinforcement (wire/strand) used for prestressing are discussed in Section 3. Prestressing can be carried out at different stages of the construction or manufacturing process. The most common, which is carried out in a manufacturing environment, is the prestressing of reinforcement before the element is cast (known as pretensioning).

Short elements may be cast in a mould and these include beams, lintels, sleepers or solid slabs and walls. Total stressing loads may be relatively small and it is possible to use the mould to resist the jacking forces arising from extending the wire/strand. However the procedures for safe prestressing should be followed in all cases.

Longer linear elements such as bridge beams, hollowcore flooring units and long-span roof elements are typically cast in a long prestressing bed. The wire/strand is extended by a predetermined amount between abutments (jacking points). This force can be over 1500 tonnes and is almost always part of a production process for 'standard' precast elements. Significant investment is required to construct the abutments and install the plant and machinery to extend the wire/strand, so commercial viability depends on repetition and standardisation to ensure volume production.

1.3 Design responsibility

Design of prestressed elements should be carried out **in consultation with a Chartered Engineer competent in prestressed concrete design**. This is frequently someone who is appointed by the manufacturer of precast prestressed products to design a product to a particular performance specification.

This means in practice that the Manufacturer's design process is clearly set out to provide design and production information to control stressing and destressing of reinforcement. This generates information that is conveyed by drawings and production schedules.

Clear design statements are required for:

1. The total design force to be applied to the element and that at the jack heads.
2. The wire or strand arrangement and any order of stressing individual or group of wires or strands.
3. The means of validating the force in each wire/strand. The load in the wire/strand should be checked by calculation, (giving extension) or by calibrated gauge (giving a load reading).
4. Information on the properties of the materials being used and the strength characteristics for reinforcement.
5. The strength of the concrete required to be attained at the time of transfer of the prestress.
6. The final strength required in the concrete at the time the element is to be put into service or assembled in the building.

The type of product often dictates the process and documentation to satisfy the above requirements but they should be verifiable in any design audit. The above design verification is

therefore embodied in the process descriptions, maintenance processes and operational procedures described in other sections of this Code.

1.4 Product type testing

Design verification is often carried out by testing prestressed elements in order to ensure that new or improved products meet the predicted requirements of design. This then forms the basis of continuous quality control to ensure consistency in manufacture.

1.5 Constituents

Prestressed concrete products are a combination of concrete and reinforcement, and this requires a careful understanding of the physical properties of both materials. For steel this principally relates to strength consistency and predictable load characteristics.

1.5.1 Concrete

Concrete is principally a combination of sand, aggregates, Portland cement and water. There needs to be special consideration of its physical properties for all phases of its life from when it is a wet plastic mouldable material to a highly resistant compression material. Additives are often included to improve concrete properties. Consideration should be given to how it gains strength and maintains a durable and fire protective barrier to the steel, and how it behaves under sustained loading. The choice of constituent materials and their proportions all have an influence.

1.5.2 Prestressing steel

The steel used for prestressing concrete is either high-tensile wire or high-tensile strand and needs to meet the requirements of (BS 5896).

1.6 Production of prestressed concrete products

A typical generic arrangement for the manufacture of prestressed concrete products is illustrated in the following flow chart that relates to flooring (Figure 1.3).

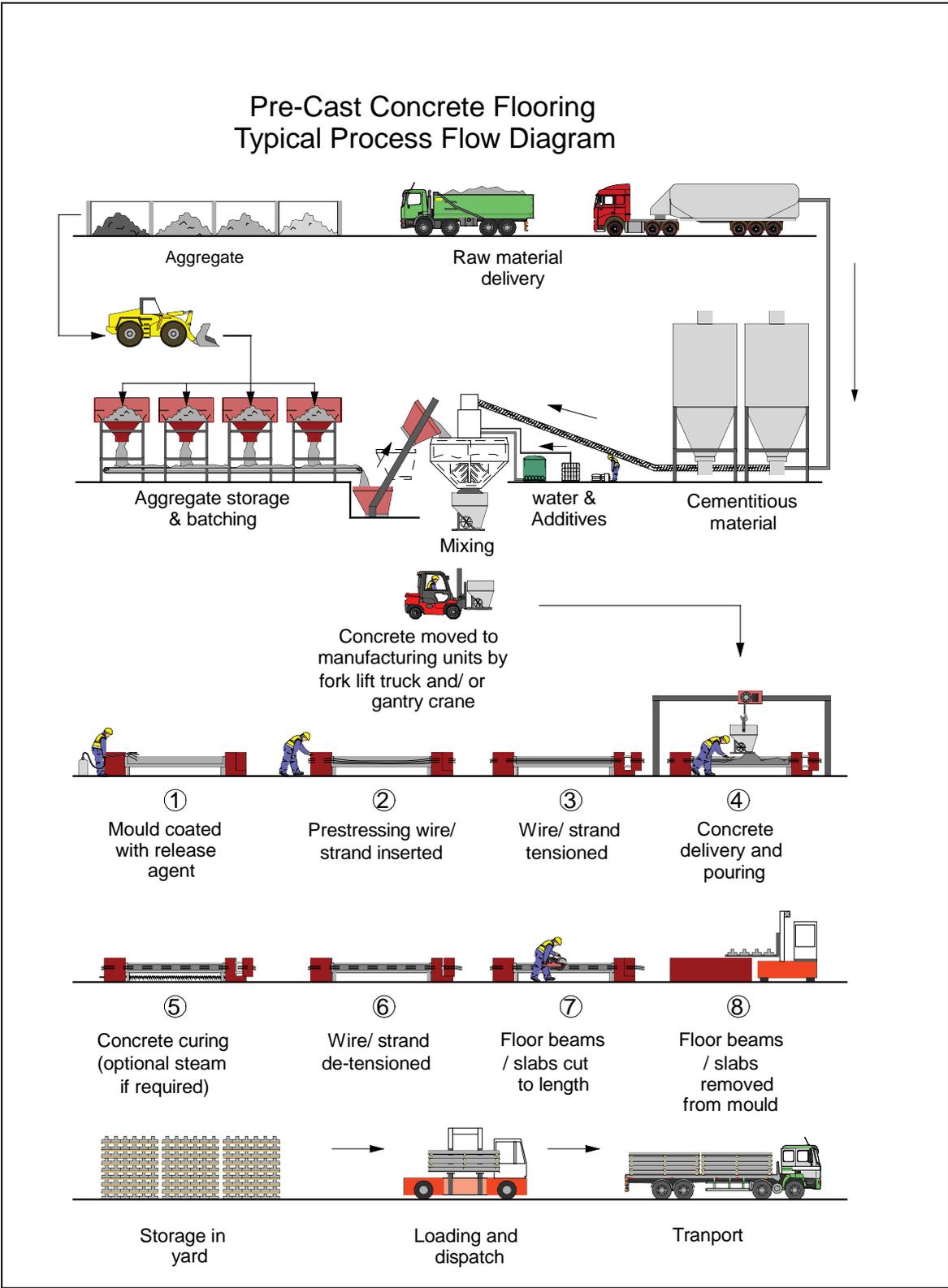


Figure 1.3
Typical process flow diagram for the manufacture of prestressed concrete flooring.

Note: Products that may be prestressed include lintels, beams, hollowcore flooring, wall panelling and bridge beams.

2 STRESSING PROCESS AND EQUIPMENT

There are two main methods of stressing:

2.2 Single wire/strand stressing

In single wire/strand stressing each wire/strand is stressed individually by using a special jack and prestressing pump that is connected to the jack with a flexible hose. The strand/wire is gripped for pulling by internal wedges and extended by the jack to a predetermined load.

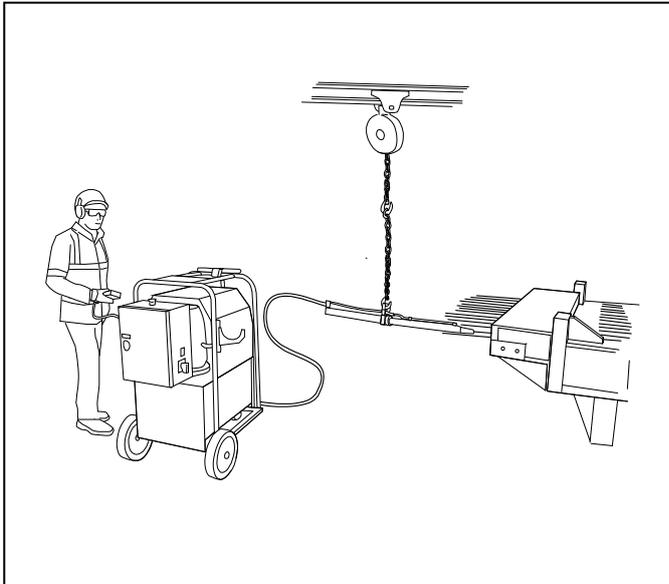


Figure 2.1
Single wire/strand stressing with a jack



Figure 2.2
Jack and stressing pump

2.1 Multi-stressing system

Multi-stressing is a method whereby the full complement of wire/strand that is held in position at the live end of the bed/mould is stressed together in one operation.

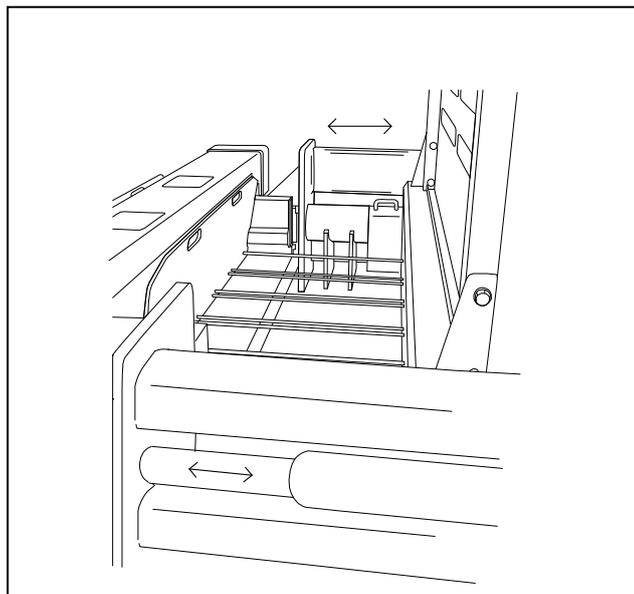


Figure 2.3
Hydraulic stressing mechanism on
mould for multi-stressing

2.3 Maintenance

When stressing jacks are used the internal wedges must be regularly checked and serviced in a similar way to the barrels and wedges used on the bed (see Section 5).

Multi-stressing systems require less maintenance; however periodic inspection of all components, particularly the hoses and couplers is required, along with checks for fatigue cracks in the steel structure and surrounding concrete. Full records should be maintained.

Care is necessary when disconnecting and reconnecting hoses to avoid contamination. Both pumps and jacks should be kept clean and require regular servicing. Jacks should be re-calibrated after a maximum period of six months. The current calibration certificate should be on file for reference and a clear indication given to the Stressing Operative of the pressure needed to achieve the correct load in the strand/wire.

Manufacturer's maintenance instructions should be followed, with oil levels being checked as part of the regular maintenance routine.

Regular services should include filter and oil changes, relief valve checks and a system check to ensure that the pressure can be held in accordance with the manufacturer's instructions.

In addition to the routine inspection of the pulling wedges, the system should be re-calibrated after any component changes to the pump or jack,

Any hydraulic leakage should be repaired immediately or the equipment taken out of service.

2.4 Moulds and stressing abutments

2.4.1 Moulds

Moulds can be either separate from the stressing elements so that they sit between the tensioned abutments and merely act as the shape former, or they can be designed to be integral with the abutment ends so that part of the stress resistance is taken through the body of the mould itself.

2.4.2 Abutments

Abutments can vary in size, shape and complexity depending upon the forces they need to resist and the shape of the elements being cast. For long prestressing beds used in the manufacture of hollowcore flooring and bridge beams, the foundation depth needed to resist the overturning motion of the prestress, which can be up to 1500 tonnes, can be several metres deep.

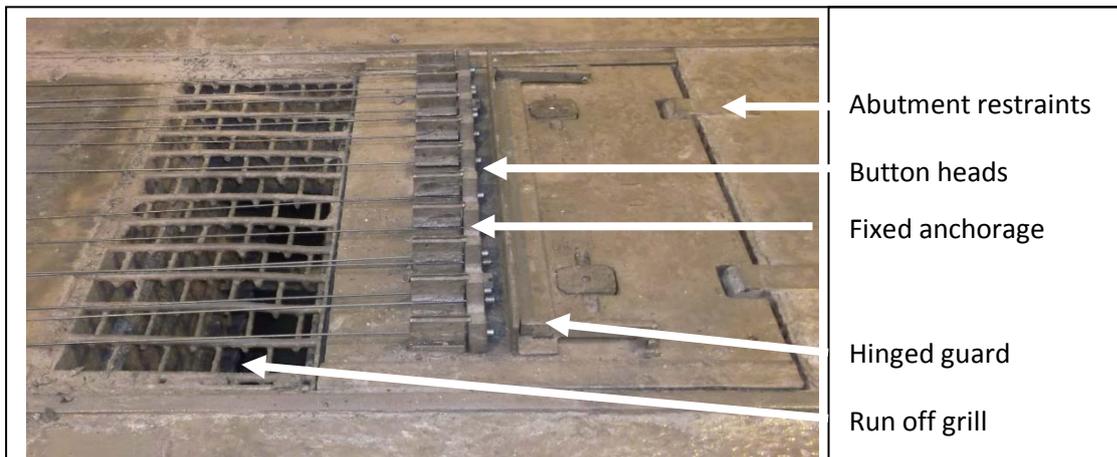


Figure 2.4

Abutment at end of hollowcore flooring casting bed.

2.4.3 Inspection and maintenance

In all cases it is essential that the structural integrity of the moulds and stressing abutments is maintained. Each company should develop its own certification and testing policy as part of the safe stressing operation.

Where possible, verification of the safe working capacity of the moulds and stressing abutments must be obtained from the manufacturer, or independent verification obtained from a suitably qualified engineer.

Any changes to the set loads and strand/wire positions should be approved in writing by the engineer responsible.

Inspection of moulds and stressing abutments must form part of the regular inspection regime of a suitably qualified engineer and should be carried out at the recommended intervals. Permanent anchorage points at both ends of the stressing bed should also be cleaned and examined by a Competent Person at periodic intervals to ensure their integrity.

It is essential that inspection records are maintained for all equipment used in the stressing process.

3 WIRE AND STRAND

3.1 Wire

Wire is a single solid length of steel that may be plain or indented and is wound into large diameter coils.

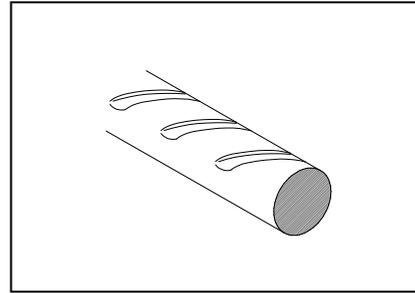


Figure 3.1
Indented wire

3.2 Strand

Strand consists of six cold-drawn wires spun together around a central wire that is then wound into coils.

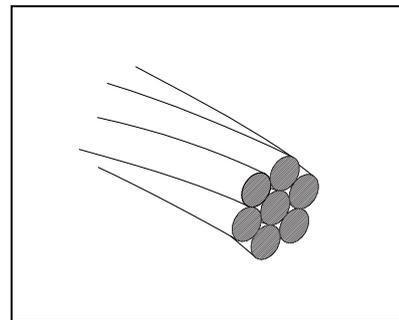


Figure 3.2
Strand

3.3 Purchase orders

Steel should be ordered according to the standards that are applicable for the concrete product that is being manufactured. In most cases that means that steel should be ordered to the British Standard for prestressing steel, *High tensile steel wire and strand for the prestressing of concrete*. BS 5896: 2012.

Steel should be purchased only from suppliers that are on a company's approved suppliers lists. It is a requirement of the British Standard for prestressing steels that steel suppliers operate a quality management system to BS EN ISO 9001. Traceability of steel is important and suppliers should be able to produce an up-to-date certification showing compliance with BS EN ISO 9001.

There is currently no harmonised European standard for prestressing steels and so there is no CE marking covering prestressing wire and strand.

To avoid any confusion, steel should be ordered using the 'steel designation' as specified within BS 5896 and the designation should consist of:

1. The number of the standard i.e. BS 5896.
2. The steel name consisting of the letter Y for prestressing steel.
3. The nominal tensile strength in MPa.
4. The letter C for cold drawn wire, or S7 for 7 wire strand.
5. The nominal diameter of the wire/strand in mm.
6. The type of indent. For wire this is T1 (triple indent/chevron) or T2 (Belgian indent), and for strand the letter I if it is to be indented.

For example, if ordering 5mm triple indented/chevron wire the designation would be BS 5896 Y 1770 C 5.0 T1.

The designations of the most common sizes ordered in the UK are given below:

5mm	(1770 grade) indented wire -	BS 5896 Y 1770 C 5.0 T1
7mm	(1670 grade) indented wire -	BS 5896 Y 1670 C 7.0 T1
9.3mm	(1770 grade) plain strand -	BS 5896-Y 1770 S7-9.3
12.5mm	(1770 grade) plain strand -	BS 5896-Y 1770 S7-12.5
9.3mm	(1770 grade) indented strand -	BS 5896 Y1860 S715.7 I

Other designations used are:

15.2mm	(1820 grade) compacted plain strand	BS 5896 Y1820 S7G-15.2
15.2mm	(1820 grade) plain strand	BS 5806 Y1860 S7-15.2
15.7mm	(1860 grade) plain strand	BS 5896 Y1860 S7-15.7

If ordering other sizes or different steel grades then refer to BS 5896:2012 for full information of the designation to be used.

3.4 Delivery

Each coil or bundle of wire or strand should carry a label giving:

- The steel designation (e.g. BS 5896 Y 1770 C 5.0 T1).
- The coil number.
- The manufacturer's name and manufacturing site.

If requested to do so, the steel supplier should supply test certificates for each coil delivered. BS 5896 does not require test certificates to be supplied unless the customer requests it; however it is good practice to request this.

3.5 Offloading and handling

Wire and strand can be offloaded from trucks using an overhead crane or by forklift trucks. The coils are very heavy (usually 2 – 4 tonnes each) and so care must be taken to handle them safely. The supplier of the steel should be consulted where any doubt exists as to the safe handling of the product. Additional information on this topic is available in the HSE publication HSG 246, *Safety in the storage and handling of steel and other metal stock* (see www.hse.gov.uk/pubns/priced/hsg246.pdf).

3.5.1 Wire

Wire is delivered in large coils on the bed of the truck; they can be unloaded using an overhead crane with lifting slings or by using a forklift truck.

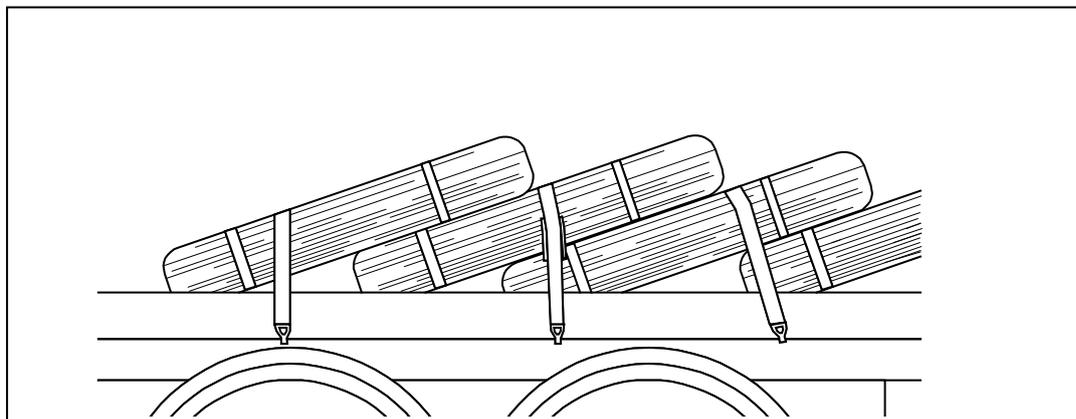


Figure 3.3
Delivery of wire

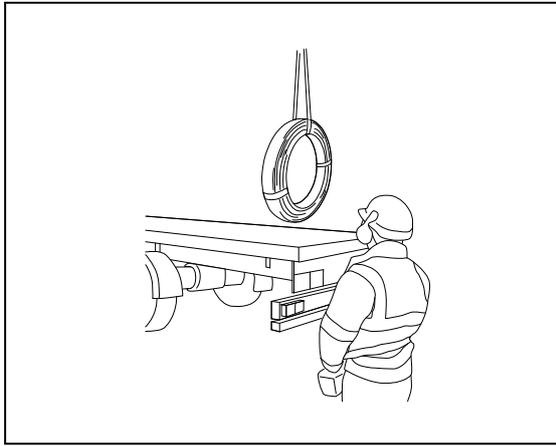


Figure 3.4
Wire unloaded by crane

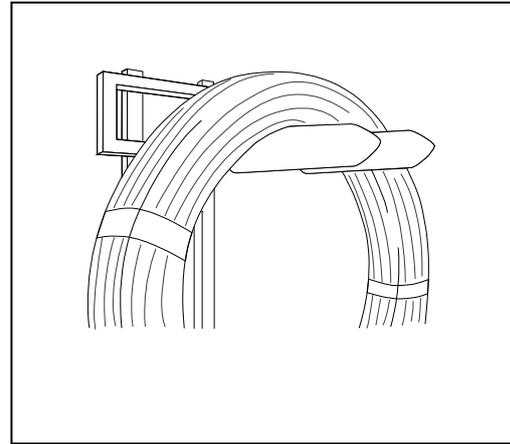


Figure 3.5
Wire unloaded by forklift

3.5.2 Strand

Strand is delivered in coils that will be laid flat ('eye to the sky') or on edge ('eye to the side').

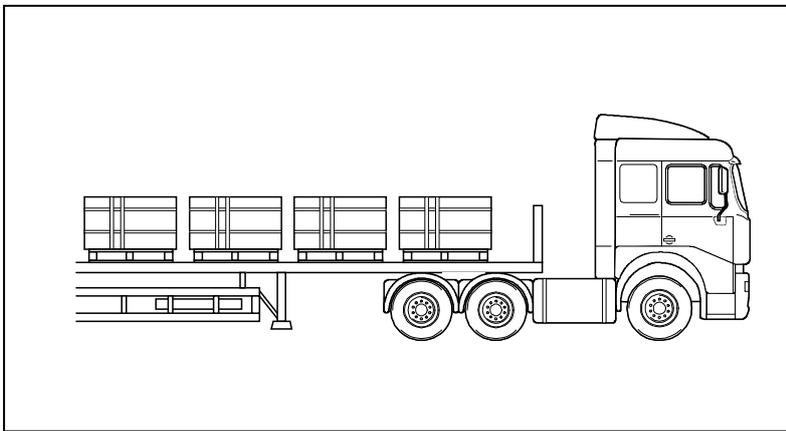


Figure 3.6
Delivery of strand coils laid flat

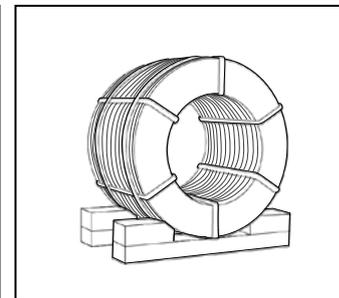


Figure 3.7
Strand coil laid on its side

Strand is best handled using a forklift truck; if an overhead crane is used it is important that the coils are not lifted with slings as this will distort them and can cause the coils to collapse. If unloading with an overhead crane a lifting bar or C hook must be used.



Figure 3.8
Label attached to strand showing safe handling

3.6 Storing wire and strand

Wire/strand should be protected when in proximity to welding operations as welding sparks can cause damage and create weak spots in the wire/ strand that may lead to failure.

3.6.1 Wire

Wire should be stored 'eye to the sky' where it will not be excessively exposed to the elements in an area where it will be free from contamination and safe from being accidentally damaged (for example by a truck). If at all possible it should be kept off the ground to encourage ventilation and drainage.

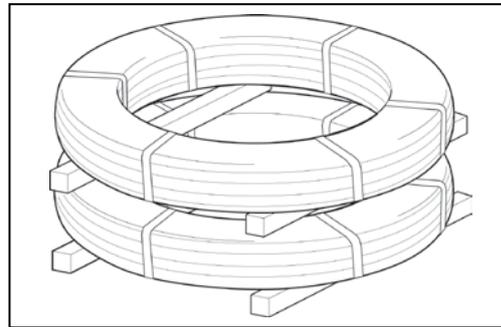


Figure 3.9
Ideal storage method for wire

3.6.2 Strand

Strand can be stored 'eye to the sky' or 'eye to the side' (see Figures 3.6 and 3.7) and should be placed where it will not be excessively exposed to the elements in an area where it will be free from contamination and safe from being accidentally damaged (for example by a truck). If at all possible it should be kept 'off the ground' to encourage ventilation and drainage

The most stable way is for coils to be placed 'eye to the sky'; this can also provide the opportunity to stack the coils up to three high. When stacking care must be taken to ensure that the ground is strong enough to take the weight, that the stacks are stable and secure.

If storing them 'eye to the side' care should be taken to ensure that the coils are prevented from rolling by using chocks or other means.

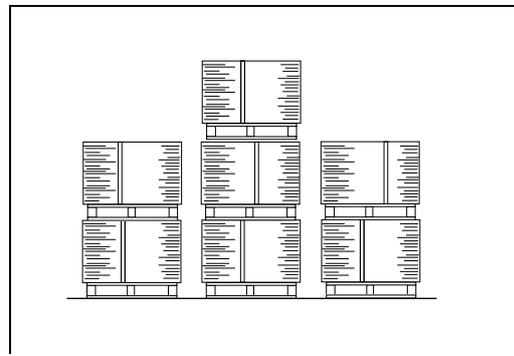


Figure 3.10
Strand stacked off the ground

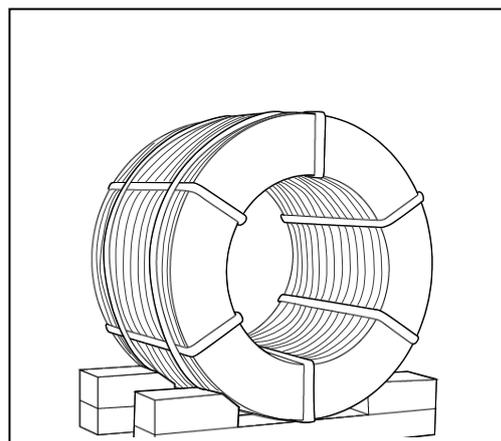


Figure 3.11
Eye-to-the-side coil supported on timber bearers.

3.7 Stock rotation

Good stock management is important as all steel products will rust over time and so it is best to adopt first in/first out stock rotation. To prevent excessive rusting, consideration should be given to how long the steel is stored and under what conditions. If the steel is to be stored for a long time, some form of extra protection should be provided, for example sheeting or storing under cover.

3.8 Cutting strapping

Strand and wire is always supplied with steel transit strapping and may also be wrapped. If the steel is wrapped it is acceptable to remove the outside steel transit straps and wrapping before placing the coils into a dispenser. Under no circumstances should internal securing straps holding the coil together be removed **before** the coil is placed in a dispenser (in the case of strand) or in the place where it will be used (in the case of wire).

When cut the steel banding is sharp and has significant spring, which can cause an injury. Eye protection, gloves and arm protection should be worn and the correct banding cutters should be used.

Please refer to the BPCF Guidance Note dated 01.09.2008 *Safe handling and cutting of product strapping*.

The steel straps must be cut using a special steel-strapping cutter; straps must not be cut using an angle grinder, hammer and chisel, or cutting torch.

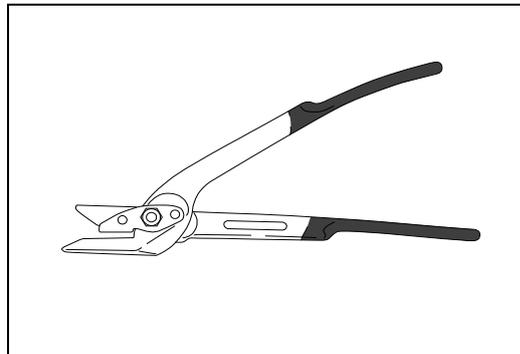


Figure 3.12
Specialist steel strap cutter

3.9 Dispensing wire and strand

There are a number of different ways of dispensing or de-coiling wire and strand. For example wire can be dispensed using a 'hangman's noose' arrangement, or from a 'lobster pot'. Strand must **always** be dispensed using a coil dispenser, it is best practice to use a dispenser that has an anti-tangling design such as a bar or 'double cone' in the centre.

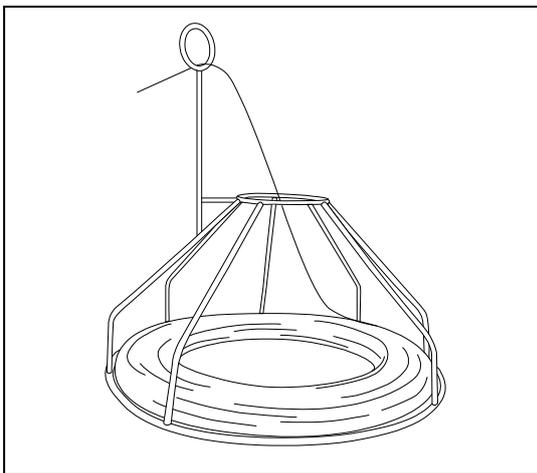


Figure 3.13
Hangman's noose arrangement for dispensing wire

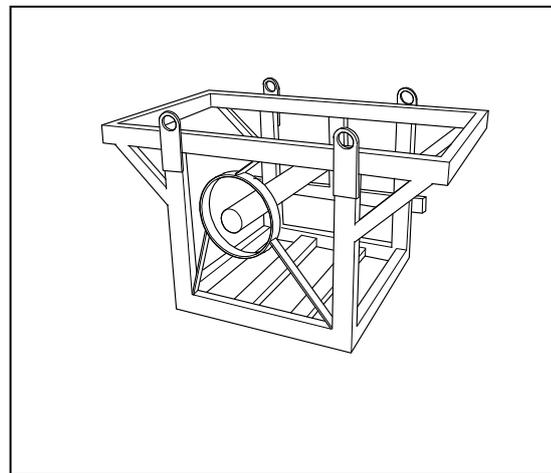


Figure 3.14
Strand dispenser with cone in centre to prevent tangling

3.9.1 Wire

It is good practice when dispensing wire to identify the top of the coil and pull from that end. Most manufacturers will identify the end of the coil with a tag/rubber bung or label.

The ground where the coil is placed for de-coiling should be flat and free draining; water should not be allowed to puddle under the coils as this will increase the risk that the steel will rust quickly. It is good practice to raise the coil off the ground. Dispensing the wire is facilitated by pulling from a high point, through a ring above the centre of the coil.

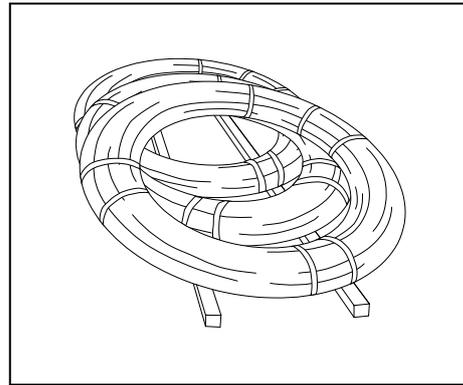


Figure 3.15
Wire coils place on timber batters

3.9.2 Damaged or kinked wire

During the handling, dispensing (or wiring up) operation operatives should carefully inspect the coils for any damaged or kinked wires. Where this occurs the damaged section should always be cut away and must **not** be used in production.



Figure 3.19
Wire kinked while still in coil



Figure 3.20
Wire/strand kinked on stressing bed

3.9.3 Strand

To prevent tangling of strand it is very important that the coils are loaded into the dispenser and pulled in the correct direction. The direction of pull will depend on whether the steel is left or right hand lay; this is determined by the direction of strand winding. Suppliers should always identify the end of the strand and show the direction of pull on the label. However if the direction is not shown, or has been lost, it can be worked out using the rule of thumb:

- If the steel is left hand lay, use your left hand and follow the direction the strand has been wound inside of the coil – your thumb will point in the direction of pull.
- If the steel is right hand lay, use your right hand and follow the direction the steel has been wound inside the coil – again your thumb will show the direction of pull.

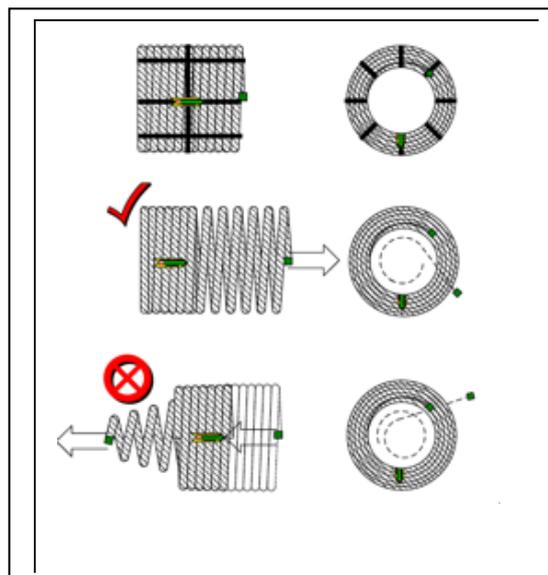


Figure 3.21
Always pull from the end indicated by the green arrow

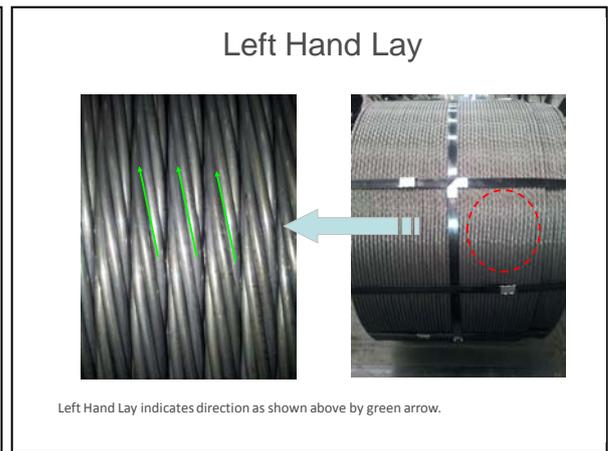
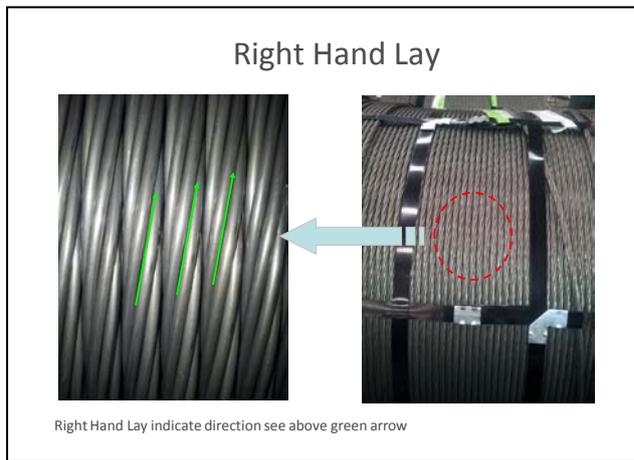


Figure 3.22

Coils of strand showing direction of lay

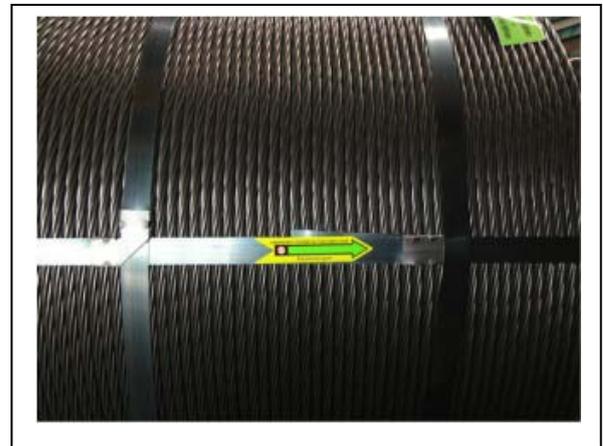


Figure 3.23

Coils of strand showing indications of where to start pulling.

3.9.4 Hot metal working

Heat applied to a stressed strand/wire can result in elongation and failure. Hot metal working should not at any time be carried out near any strand/wire, particularly if it has been stressed. Should work of this nature be required the strand/wire should be de-tensioned and protected. Also care should be taken with electric cable as it may cause a short or arc which could damage the strand/wire.

4 WIRING UP THE BED

4.1 Running wires/strand

There are several methods that can be employed in running the wires/strands down a stressing bed; the method employed will depend on the site and the product. They can be run after dispensing and cutting, or they can be dispensed straight into the bed and cut accordingly. It is important not to damage the wire/strand at any time as this could cause failures during the stressing process. All wires/strands should be checked to ensure they are in line, not crossed, have no tangles, kinks or damage and they must be correctly positioned on the bridges at both ends of the bed.

When pulling wire/strand from a dispenser either by hand or with a machine it is important to allow it to rotate freely. If restrained by grabbing or clamping the strand will build up pressure and can cause injury and damage.

When pulled by hand, the correct gloves with a hard palm should be used so that the lay of the strand does not trap the material of the glove or skin and cause a sprain injury or worse.

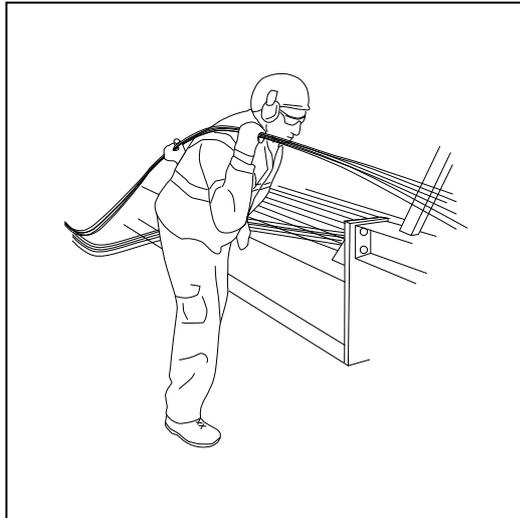


Figure 4.1
Pulling by hand

Due to the bed lengths it is common practise to pull or tow a single wire/strand or several together with a type of pulling trolley or other suitably adapted equipment. When pulled mechanically the wire/strand should be allowed to rotate freely.

Strand pushers and 'rabbits' can be used to push or pull the wire/strand down a track or area away from the beds. Care is required with all systems to ensure that the wire/strand is able to rotate freely and is effectively controlled with suitable guarding to protect personnel from any rogue flaying wire/strand during dispensing and preparation.

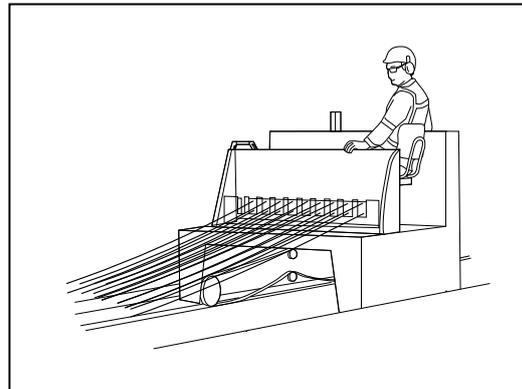


Figure 4.2
Pulling by machine

Figure 4.3

Rabbit mechanism on raised track for pulling pre-determined lengths of wire/strand



4.2 Cutting wire/strand

The material used in the production of the stressing wire/strand is high-tensile steel and as such is difficult to cut. The following details apply to cutting both un-stressed and stressed wires/strands using either an angle grinder or a bolt cropper.

Both methods have requirements and safety implications that can change depending in which circumstances they are used. Careful consideration should be given to ensure the safest means possible is used for each task. Stressed strand poses an added risk as individual strands have a tendency to unwind as they are cut and behave in an unpredictable manner, putting the operator in danger

When cutting stressed wire/strand, extra consideration must be given to the position of the cut in relation to the amount of free wire/strand present and its direction of travel when cut. When deciding how to control the risks during cutting attention should be paid to guarding, restraint and operator position.

It is not advisable to use gas or plasma to cut free strand or wire.

4.3 Angle grinders

The most commonly used cutter, an angle grinder requires suitable PPE including gloves, Grade 1 impact lens goggles/mask and protective clothing. **Normal safety glasses do not meet the legal requirements.** When cutting un-stressed wire/strand it should be placed on a timber packing as opposed to concrete or steel to minimise the risk of flying debris. This also extends the life of the grinding disc.

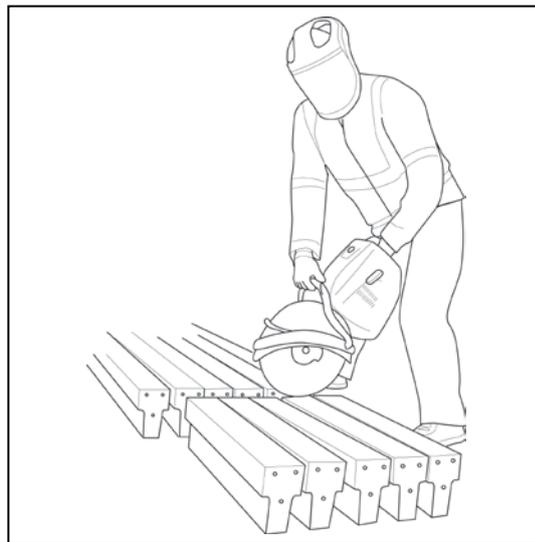


Figure 4.4
Cutting T-beams using an angle grinder

4.4 Bolt croppers

Bolt croppers can be manual, hydraulic or pneumatically operated; the size should be determined by the diameter of the steel being cut. Similar PPE, including gloves, Grade 1 impact lens goggles/mask and protective clothing is recommended, with additional precautions being necessary with pneumatically operated equipment due to the use of compressed air.

5 BARRELS AND WEDGES

Barrels and wedges are placed over both ends of the wires/strands once they have been passed through the locating holes in the stressing heads/abutments. Used in combination they lock to grip the ends to form the main resistor to the wire/strand slipping through the locating hole in the stressing heads after stressing.

5.1 Procurement of stressing components

All stressing equipment and anchors used in the precast concrete industry should be manufactured in accordance with recognised standards and should be marked accordingly. At a minimum, precast wedges should be marked with the manufacturer's name, size, and where space allows, the batch traceability marking. Precast barrels should have the manufacturer's name, maximum load rating and batch traceability markings. The manufacturer should be externally certified to a recognised Quality Management System (e.g. BS EN ISO 9001: 2008). The manufacturer's certificate of conformity to their inspection plan and quality management procedures should be available upon request.

Components from different manufacturers **cannot be mixed** and control systems should be in place to ensure that this mixing does not take place.

5.2 Storage

The barrels and wedges should be stored in a dry atmosphere, away from moisture and not immersed in oil.

The wear rate on a set of wedges should be equal to avoid tearing of the strand/wire when they grip the steel. Stock rotation should be considered to ensure even wear on the wedges.



Figure 5.1
Barrel dispenser

5.3 Inspection, cleaning and lubrication

A dirty or worn wedge can fail by allowing the wire/strand to slip out of the anchor under load, with catastrophic consequences.

Barrels should be checked for wear using an appropriate tool this can be done in house or outsourced to a specialist company.

The rate of cleaning for barrels and wedges will differ from site to site depending on the environment in which it is used and the frequency of use. Ideally the anchor should be cleaned and inspected after every use. A Competent Person should, with reference to the supplier's instructions and in consultation with the supplier, ensure that the barrels and wedges are cleaned, inspected and lubricated using the correct lubricant. When cleaning, care should be taken to remove any dirt from the teeth and on the segment joining faces as this will affect the grip's performance. Wedges are normally supplied with a rubber O ring or steel circlip to hold

the segments together. It is important that these are fitted and in good condition to control the wedges during use.

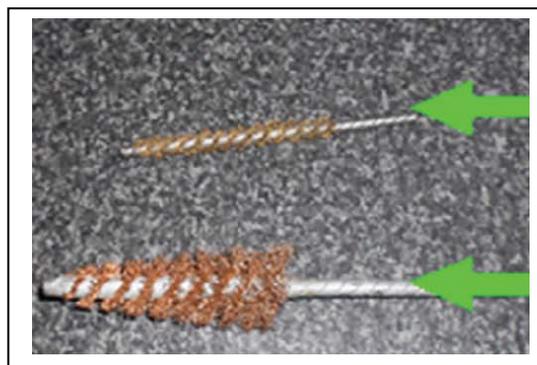


Figure 5.2

Left: Cleaning a wedge Right: Brushes for cleaning wedges (top) and barrels (bottom).

Accurate steel insert tools are available from barrel manufacturers, and should be used to check barrel wear.

All wedges are manufactured using case hardened steels and tooth damage can expose the softer base material which has little or no capacity to grip the hard steel tendons. The wedge teeth should be inspected with great care to ensure that the tooth form is sharp and undamaged and, if not, they should be replaced.



Figure 5.3

Steel insert tools for measuring barrel wear.

Springs used in spring-loaded anchors (SLAs) and double-ended joiners (DEJs) also known as wire/strand couplers, should be changed regularly, particularly if used on beds that are subject to shock de-tensioning.

When looked after well, barrels can last for many years. They may, however, eventually suffer from wear, damage and metal fatigue. For precast manufacturers who regularly inspect and frequently replace components, there is reduced likelihood of failure by fatigue.

Anchor maintenance should be carried out regularly and consistently in an area away from production, by personnel not involved in the production process.

Inspection of the barrels and wedges must be carried out in good light with the aid of a magnifying glass. These inspections may require the use of more sophisticated equipment, for example a magnifying glass with calibrated reference lines or a microscope.



Figure 5.4

Correct procedure for examining wedges

Reject items must be removed from the production immediately to prevent their reuse.

Every six months inspection of the barrels and wedges should be carried out by another inspector.

5.4 Identifying barrels and wedges

Manufacturers of wedges should mark them with the wire/strand size and the barrels should be marked with a maximum stressing load capacity. This **is not** the site stressing load and reference to the site's Design Engineers should be made to determine the required load. They should also be marked with a traceability code.

Wire/strand restraints come in five versions

- Open barrel and wedges
- Enclosed (spring-loaded) wedges
- Bayonet caps
- Wire/strand couplers (double ended joints)
- Button headings

5.4.1 Open barrels and wedges

Open barrels and wedges are the most common in use at the live end with a jack that has a secondary function to lock off the wedge with a small piston at the end of the jack. The jack can, however, also be used at the dead end where care is necessary to ensure that the wedge is 'locked off' by tapping the wedge firmly into the barrel.

The use of 'O' rings or circlips is important to ensure alignment of the segments, and they should be regularly changed.

Advantages of open wedges:

- Ease of cleaning and maintenance.
- The wedge can be inspected during use.
- Low component count.

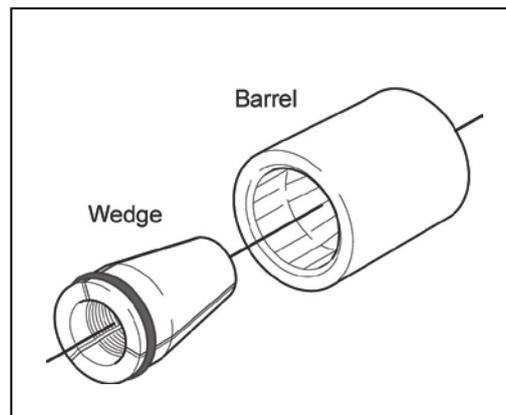
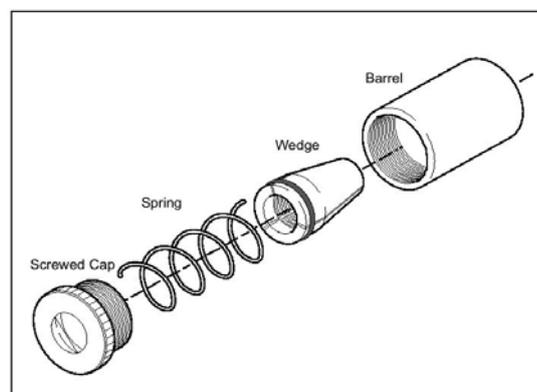


Figure 5.5
Open barrel and wedge

5.4.2 Enclosed (spring-loaded) barrels and wedges

The spring loaded grip should normally be used at the non-stressing end of a bed, but when prestressing is carried out using a jack without power lock-off, they may be used with care at the stressing end of the bed. It should be noted that, when used in this way, the 'lock off' loss (where the wedge is pulled into the barrel resulting in some loss of prestress) may be high, particularly on shorter beds.

It is vital that the springs are in good condition to ensure the safe use of SLAs and DEJs. They should be changed regularly, especially when they are damaged by 'shock de-tensioning'.



Enclosed Barrel and Wedge

Figure 5.6
Enclosed barrel and wedge

5.4.3 Bayonet cap

Bayonet cap anchors feature a quick and easy release mechanism to facilitate inspection and cleaning of the wedges. They should normally be used at the non-stressing end of a bed

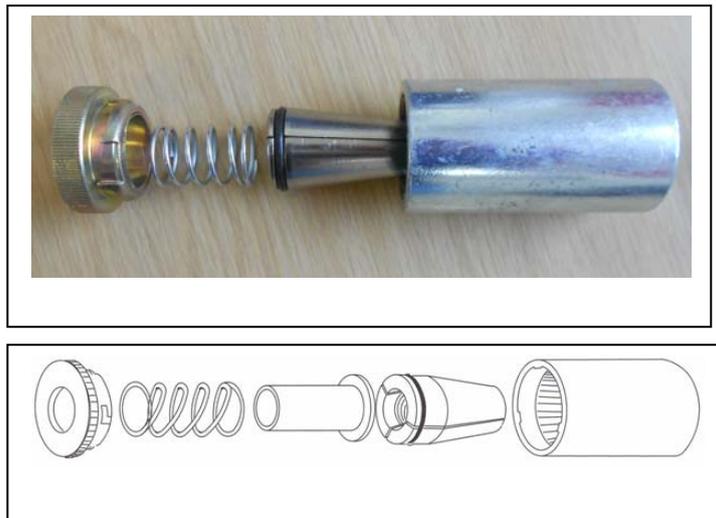


Figure 5.7
Bayonet cap

5.4.4 Wire/strand coupler (also known as double ended joiner or DEJ)

Wire/strand couplers are used to connect two lengths of wire/strand. This enables reductions in wastage, as the wire/strand may be re-used when the pre-stressing bed is only partially filled. The large hexagon or knurled centre plug promotes easy assembly.

Note that this type of anchor should be used with care as the end of the strand is enclosed in the wedge. As a result it is difficult to ensure that the strand has been fully inserted and hard to monitor any slip of the strand in the anchor.

A safe working system should ensure that the strand is marked so that when it has been fully inserted a mark is visible and will confirm that the anchor is performing correctly.

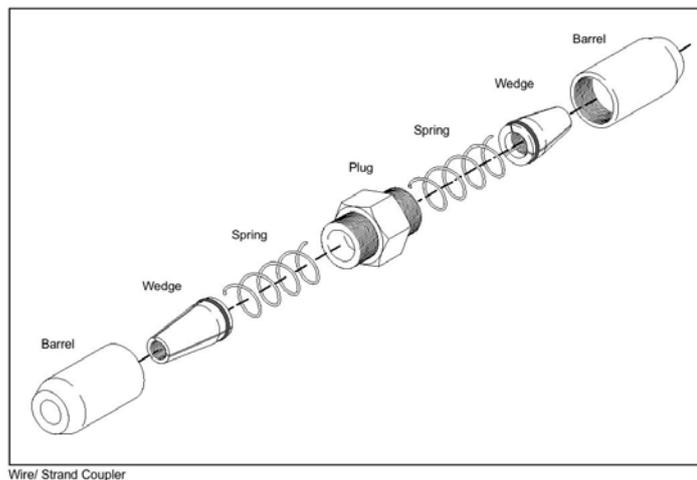


Figure 5.8
A wire/strand coupler

5.4.5 Button headings

Button headings can be used instead of barrels and wedges on wire systems. Used mainly in multi-stressing applications, the wires are cut to a precise length and a hardened steel ferrule is positioned as shown in Figure 5.9 prior to upsetting the end of the wire (buttoning).

For safe operation a test procedure should be introduced to confirm the tension at failure.

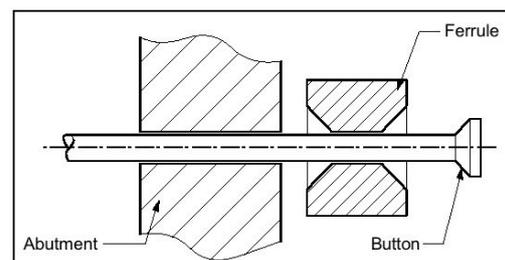


Figure 5.9
Button heading

5.5 Fitting the barrels and wedges

When fitting the grips to the stressing wires/strand there are important factors to be considered:

- Is it the correct grip for the application?
- Is the grip the correct size for the wire/strand?
- Is it clean and correctly lubricated?
- Are the teeth in good condition?
- Is the O ring serviceable?
- Is the spring full length?
- Has the grip been correctly locked off?

Failure to consider these factors could result in a grip failure.

Wedges and barrels at the non-stressing end must be seated correctly with the wire/strand projecting at least 100mm.

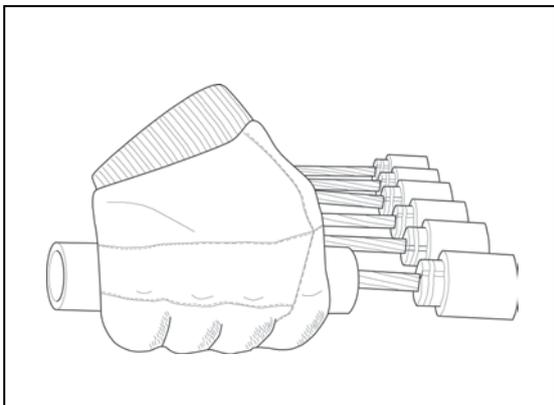


Figure 5.10
Fitting barrel and wedge

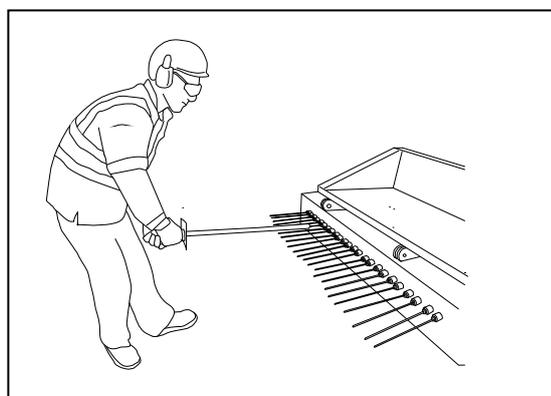


Figure 5.11
Wire/strand projecting by a minimum of 100 mm.

6 STRESSING

6.1 Methods of stressing

Wires/strands can be extended either singly or by pulling all the wires/strands together (multi stressing). When setting up a production site, consideration should be given to the method of stressing that will take place and whether single or multi stressing is appropriate for manufacture of the product.

6.1.1 Single wire/strand stressing

A stressing jack is used to stress a single wire/strand at a time. It is the choice of the manufacturer whether to tension the wire/strand in a single pull or by multiple pulls depending on the length of the stressing bed, and to choose the length of the stressing jack accordingly. The degree of tension applied to each wire/strand must be pre-determined by a Competent Person. It is also important to include manual handling of the stressing equipment within the risk assessments with particular regard to its weight and manoeuvrability.

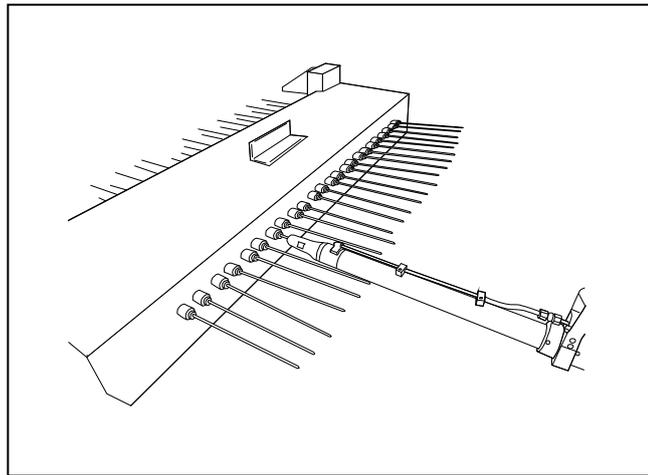


Figure 6.1
Stressing a single wire/strand with a jack

Each wire/strand is stressed to the required load using a pressure measurement device on the pump or a load cell in the jack, calibrated to the actual load in the wire/strand. It is safety critical that the wire/strand is not overstressed and the pump must be fitted with a pressure relief valve to ensure this does not occur. There are both keyed and un-keyed stressing jacks available. An un-keyed stressing jack will give a longer extension reading due to turning of the strand during loading. Periodic checking of the applied load should be carried out by a suitable method e.g. deflection test, tension meter.

The setting of the pressure relief valve should be checked and set for each wire/strand configuration. Single strand stressing requires a safe system of work to ensure there is no dependency on the HPS relief valve.

Single wire/strand stressing requires a high degree of care in determining safe systems of work as a failure at the dead end can result in the wire/strand being pushed violently through the jack. Process and equipment should be provided to protect the stressing operatives during stressing as well as others who may be working beside the bed containing the stressed strands/cables (see Section 6.4 Guarding).

At no time should the operator stand in line with a jack or stressed strand/wire during or after stressing, as unplanned release of the stressed strand/wire can lead to serious injury or fatality.

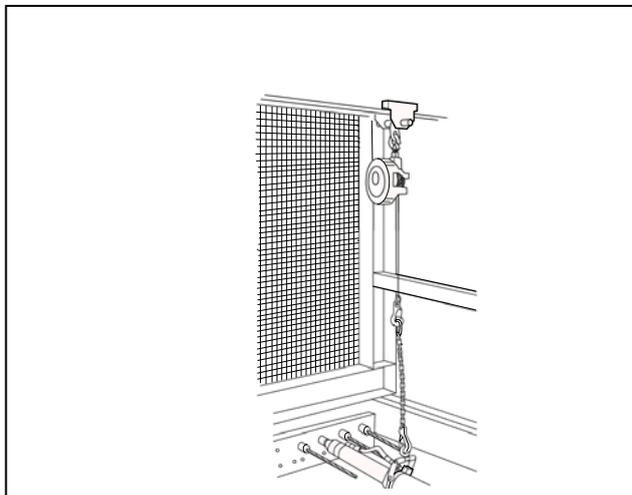


Figure 6.2
Jack supported off overhead pulley.

During stressing of strands. A special risk prevails **during** the period of stressing and elongation of the wire/strand, so at this time the greatest exclusion zone should be considered. This often requires that personnel in the area are limited to two operatives working from both sides of the live stressing end. Stressing of wires/strands to a prescribed order for the designed pattern is desirable. In certain circumstances, in the absence of a specified order, stressing starts from the centre of the group and works outwards, requiring the operatives to pass the stressing gun between themselves to stress alternate wires/strands away from the centre of the pattern. If staged stressing/elongation is required, then this is repeated after an appropriate time has elapsed and bedding of barrels and wedges is confirmed. During this period an exclusion zone is imposed and only operatives authorised for stressing are allowed in the area.

Precautions after completion of stressing. Once stressing is completed, exclusion barriers are placed close around both ends to prevent **all** operatives accessing the area behind the anchorages. The exclusion zone is only then reduced, but includes as a minimum that area immediately behind the wires/strands of both the dead and live ends. Exclusion barriers can also act as end guards.

Under no circumstances should the operator stand in line with a jack or stressed wire/strand during stressing or even when stressing is complete. Unplanned release of the stressed wire/strand can lead to the risk of serious injury or fatality. Guarding should cover the exposed wire/strands once stressed.

End guards should be fitted with timber or other material capable of absorbing the energy from wires/strands. Once they are stressed, guards should be lowered over the ends of the wires/strands to fully enclose them.

6.1.2 Multi wire/strand stressing

This system is employed in high volume production and allows for all wires/strands to be tensioned at the same time. The abutment at the end of the bed is 'live' and moves under the direction of a single or multiple hydraulic cylinders to a predetermined extension. Operators can then fit locking collars/chocks and guards into position and casting can commence. It is safety critical that the wire/strand is not overstressed and the pump must be fitted with a pressure relief valve to ensure this. Periodic checking of the applied load should be carried out by a suitable method e.g. deflection test, tension meter.



Figure 6.3
Multi-stressing mould in tensioned position.
Arrow indicates direction of pull

6.2 Placing safety restraints

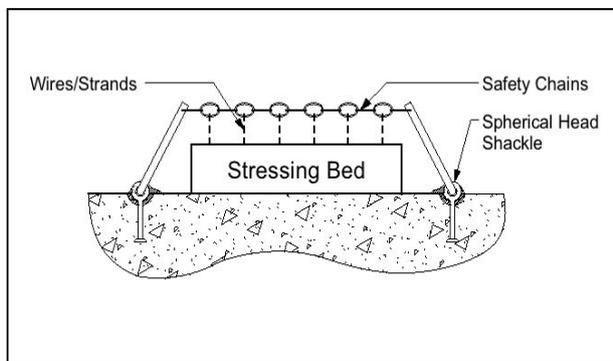
When released, the stored energy in a stressed wire or strand can cause severe injuries and in some instances these can be fatal; therefore it is crucial to restrain them adequately. Once a wire/strand is shock released it will initially travel along the same axis as that in which it was stressed. The direction will change once it makes contact with the stressing bed or other structures and can be extremely unpredictable.

It must also be realised that this movement of the wire/strand will occur in milliseconds and therefore a person will be unable to avoid it.



Figure 6.4
Wire restraint secured over hollowcore flooring bed.

In order to minimise the movement of the wire/strand when failure occurs and the tension is released, it is recommended that the stressing bed be fitted with restraints at roughly equal centres along its length. The entire length should be considered from dead end anchor to live end anchor. This is particularly important on open beds used for long-line machine casting when there is no restraint from stop ends, cages and deflector plates.



Placing of Safety Chains



Figure 6.6

Restraint bar placed over T-beam casting bed.

Figure 6.5

Section through casting bed showing safety chains.

Restraints can include chains, straps, bars, and bulk heads and should be at centres determined by risk assessment, but generally no greater than 10 m apart. All restraints, including the securing points, must be able to withstand the forces generated by a release of the wire/strand to avoid failure and maximise containment.

The Stressing Operative should carry out a daily visual inspection of all safety restraints and securing points.

Unpredictable ricochet or rebound is possible during an uncontrolled release and consideration should be given to deflections of wire/strand caused by objects around the stressing line, for example walls, ceilings and equipment. This may affect how many restraints are required during the stressing process and where they are positioned. It will also affect the design and positioning of the guards.

The use of hardwood timber (or other absorbent material) as a lining for guards, barriers and sometimes abutments is recommended. The wire/strand is more likely to embed into timber rather than ricochet, so timber increases the chance of containment during an uncontrolled release. The effectiveness of the timber will increase as its thickness increases.

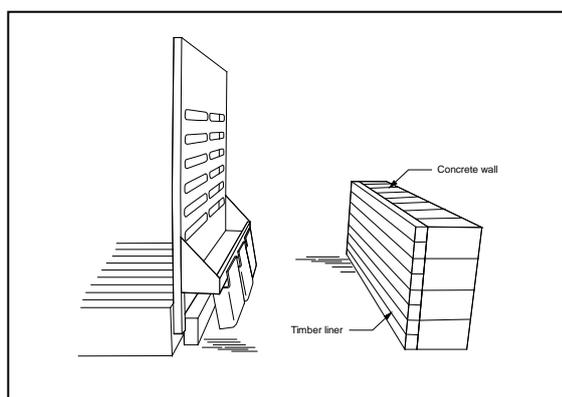


Figure 6.7

Guard at end of stressing mould with absorbent timber facing.

Any restraints should remain in place throughout the production process until casting occurs; only being removed when process dictates e.g. a casting machine travelling along the stressing line. Where possible, machines travelling over exposed wire/strand should be kept to a minimum. Operatives should always be aware of other equipment that may now be in place such as stop ends and fixed wire/strand pattern plates that may also act as a form of restraint depending on their design.

6.3 Stressing load checks

For single wire/strand stressing, the load in a wire/strand is set by the correct calibrated pump and jack.

For multi-stressing the bed can be calibrated in a similar manner by installing a load cell between the anchor and the abutment for a chosen strand/wire and the load recorded against the extension.

For both techniques independent checks on the load can be carried out after stressing is complete. Two types of meters are available for this function.

1. Voigt Meter. This equipment indicates the load in the strand/wire as it is deflected between two fixed points. By deflecting the strand/wire a given distance from the load restraint a direct read out is available of the tensile load.
2. Digiforce meter. This measures the frequency with which a wire/strand vibrates when struck. The frequency, which is a function of the tensile stress in the wire/strand and the distance between restraints, is measured by a hand-held calibrated meter that provides a read out in decanewtons

6.4 Guarding

Guarding is required to ensure protection of the stressing operator during stressing and of all personnel after stressing is complete. Fixed or distance guarding or a combination of both can be used as well as cages and/or pits for the stressing operators.

A Risk Assessment must be undertaken to ensure that all failure modes are considered and protection provided.

Those areas that are considered to be hazardous zones during stressing should be identified and communicated to all personnel who work either in or are likely to enter a prestressing factory. Only those who are trained, authorised and essential to the stressing process should be involved in the prestressing process, with all other persons being excluded from the hazardous zones. Some or all of these zones may remain hazardous to varying degrees until de-stressing takes place; guarding and work procedures should reflect this. At no time should a person be permitted to be directly in line with an unguarded stressed wire/strand.

The hazardous zones should be delineated by consideration of the likely movement of the wire/strand should an uncontrolled release occur, and should be clearly identified. The zones will also be dictated by the type of stressing system, the restraint used during stressing and the type of guards used as part of the stressing operation.



Figure 6.8

Stressing end of a wet-cast T-beam. Left: guard raised showing timber insert used to absorb impact
Right: Guard lowered to contain all prestressed wires/strands.

After stressing is complete the anchors at both ends should be checked to ensure that no slip has occurred and all guards are in place before the bed operators are allowed back into the hazardous area. As previously mentioned all guards should be in place prior to stressing if possible. To avoid lifting guards to check for slippage after stressing is complete a paint line can be applied close to the abutment before stressing that will allow slippage to be identified.

6.5 Warning systems

To ensure awareness for operating personnel and visitors when stressing is taking place suitable warning systems should be installed; these could include lights, sirens and notices.

6.5.1 Lights

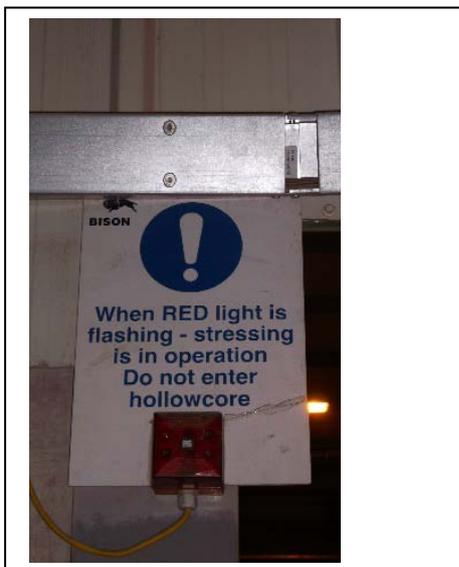
A flashing light system should be installed that is visible from both ends of the bed to indicate that stressing is in progress. Depending on the layout of the manufacturing unit, warning lights outside of the stressing area could be considered for advance warning.

6.5.2 Sirens

It is good practice to use an audible warning to support a visual system

6.5.3 Notices

Warning notices are recommended at all access points indicating that stressing is hazardous and that access is restricted when the lights or sirens are in operation.



Figures 6.9, 6.10 and 6.11
Examples of warning notices

7 CONCRETE CASTING

There are several methods of casting prestressed elements but they basically fall into two categories, machine casting and wet casting. Every manufacturing operation will be different and must be risk assessed in full. Some considerations are discussed below.

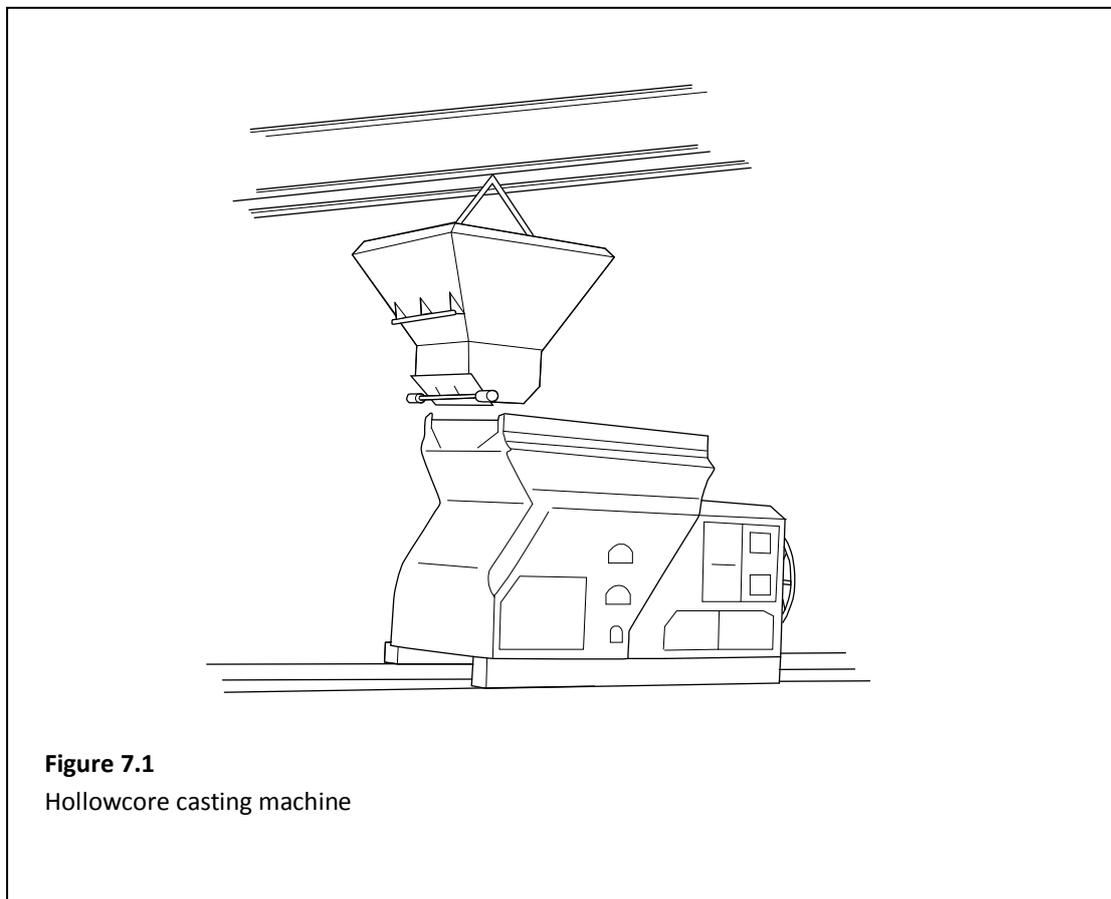
During any type of casting it is important to remember to use restraints on the wire/strand for as long as possible and not to overload or damage the wire/strand by putting machines or heavy equipment directly onto them.

7.1 Machine casting

Machine casting includes extrusion /slip form casting

With products such as hollowcore flooring there is often a requirement to create various shapes in the product immediately after forming. These could include open cores, shaped ends, holes and notches; in all cases particular care has to be taken to ensure that the wires/strands are not damaged during the process as they will still be in a fully stressed state. Marking out of the desired lengths and shapes will also take place at this stage.

Some processes permit longitudinal cutting at this early stage whereby the element is cut to narrower widths by a purpose designed bed saw. The cuts are made between the stressed wires/strand whilst the product is still in its uncured or 'green' state. This reduces the time taken and the wear on the post-cast saw.



7.2 Wet casting

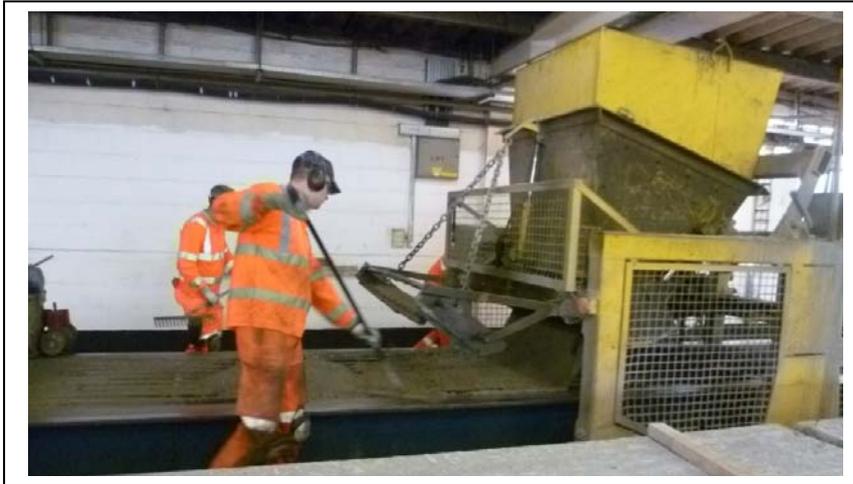


Figure 7.2
Wet casting T-beams

In a wet cast process the concrete mix is designed to flow around the stressing wires/strands that are placed within a specially shaped mould that forms the final shape of the element. Compaction can be assisted with external vibration that could include clamp-on vibrators, beam vibrators or vibrating pokers. Extreme care should be taken with pokers so as not to damage the wires/strands.

Constant vibration can seriously reduce the life expectancy of a mould and daily checks should be made to ensure that it is not showing signs of cracks, twisting or opening of seams. All damage should be repaired as soon as possible.

Self-compacting concrete can be used in many situations; this removes much of the risks and damage caused by the various forms of vibration and can also increase the life expectancy of the mould.

7.3 Concrete strength

Concrete strength should be checked before de-stressing and to check for design strength. This can be achieved in two ways:

- On cubes cured on the bed – for transfer (ie minimum for de-stressing) and in temperature controlled rooms for 28-day design strengths
- By the Maturity Method, which analyses the time and temperature profile of concrete to allow correlation figures to be established with the strength of concrete.

The time required for the concrete to achieve its required strength must be determined by a Competent Person. De-stressing **must not** be undertaken until such time as the concrete has achieved sufficient maturity to prevent loss of tension.

8 DE-STRESSING

The term de-stressing refers to the removal of tension in the wire/strand and it normally occurs once the transfer strength of the concrete has been achieved. De-stressing may also be necessary prior to casting, due, for example, to crossed wires/strands that can occur during setting up of the beds. The de-stressing operation can be a high risk activity, whether the tension is released in a controlled manner (soft de-tensioning) or in an uncontrolled manner (shock de-stressing). Care is necessary and normal stressing precautions need to be taken.

The de-stressing of stressed wires/strands can require the loading to exceed the normal 70% of guaranteed ultimate tensile strength (GUTS). This is due to higher loads being applied initially to remove the chocks or stops inserted during the stressing operation.

Slip in the anchors or in the product after de-stressing can be monitored by marking a straight line across the wire/strand close to the abutment before stressing commences, at the dead end or at both ends. This is particularly valuable when multi-stressing or when the anchors are covered with guards and the ends of the strand or wire are not visible.

8.1 Multi wire/strand de-stressing

The safest way to de-stress a multiple wire/strand stressing bed is by using special rams built in to the ends of the bed. These will allow multi-de-stressing to take place, eliminating both off-centre loadings and shock loads. The tension in the wire/strand is first increased slightly, just enough to allow removal of the locking collars/chocks. Once these are removed then the load is slowly released until the multi-stressing head is in a fully retracted position and no load remains on the free wire/strand.

8.2 Single wire/strand de-stressing

Single wire/strand de-stressing is potentially more hazardous and requires greater care to eliminate both off-centre loadings and shock loads. The load in the wire/strand can be released using either a special stressing jack nose or a bespoke tool; in both cases the supplier's instructions should be adhered to, following a set sequence of work if set down.

8.3.1 Shock de-stressing

Shock de-stressing, where the wires/strands are cut with either a gas torch or disc cutter, should be carried out with care as in both cases the unrestrained ends of the wires/strands have a tendency to retract suddenly, and in the case of strands can splay out in an unpredictable way. Extreme care must be taken when cutting wires/strands and operatives need to stand in a position of safety where the retracting wires will not strike them upon releasing the stored energy.

9 REMOVING BARRELS AND WEDGES

The removal of the barrels and wedges from the wires/strands after use is aided by the correct use of release agent. If removal by hand is found to be difficult it can be achieved by using the hydraulic jack. Once the tail ends of the wires/strands are removed from the stressing beds, re-application of the jacks to the grips will easily pull the wedges from the bores of the barrels. Use of a hammer **is not** recommended as this can produce stress cracks in the fittings. Where there is insufficient wire/strand length to allow a jack to be used, special barrel release tools are available from the grip manufacturers. This applies especially when joiners are being used as they will require total dismantling. Supplies of these specialist tools should be available at all times to reduce the risk of operators resorting to incorrect methods of barrel and wedge removal.

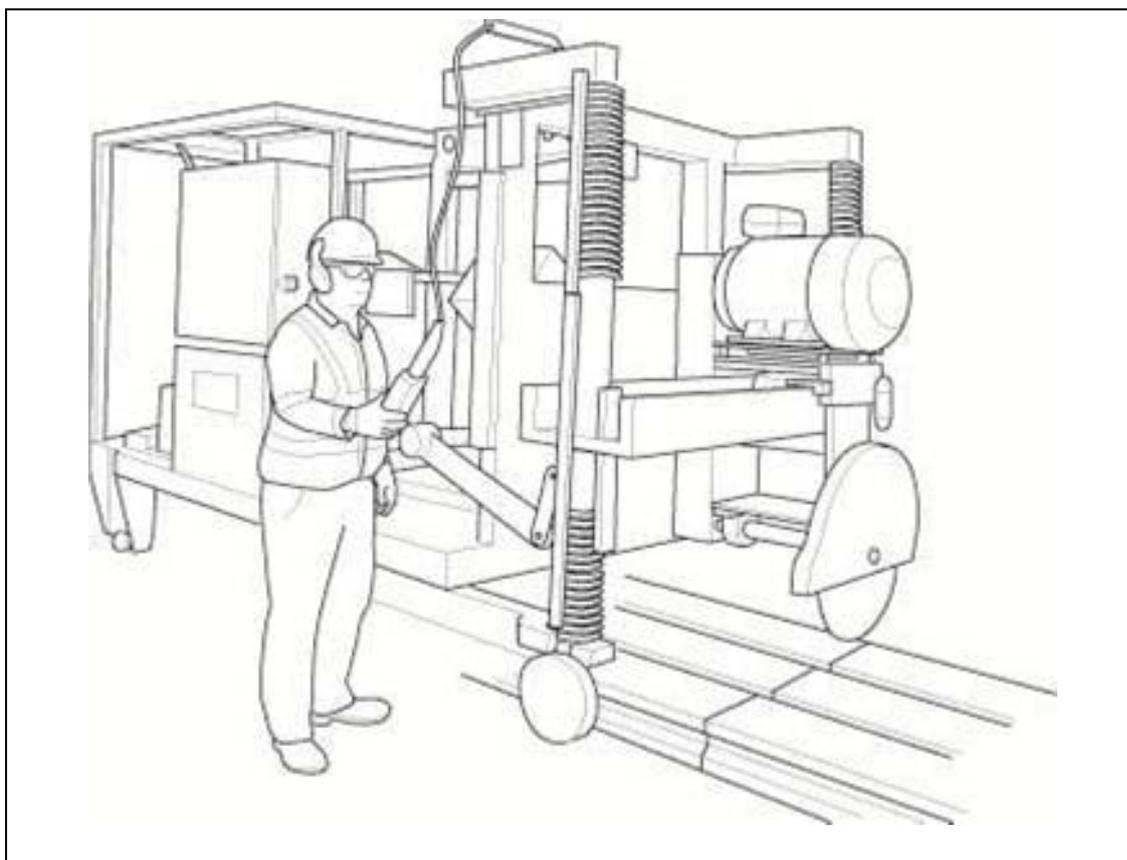


Figure 9.1

Cutting hollowcore units after de-stressing

APPENDIX A: Training, certification and competence

1 Introduction

British Precast is committed to ensuring that all operatives involved in stressing activities carried out by its member companies are competent. This includes ensuring a good understanding of the objectives of this *Code of Practice for the safe stressing of precast concrete components*. The Company should assess the level of training an individual has achieved and should provide training, instruction and refresher training as required.

2 Scope

The training that applies to Precast Designers, Managers, Supervisors, Foremen and Operatives. 'General Awareness' training is also relevant to all personnel who may be exposed at some time to a prestressing environment.

3 Responsibility

It is the responsibility of the Company employing the individual(s) and sub-contractors to ensure that they have the appropriate experience and training in the stressing of precast concrete products for them to carry out the tasks allocated to them, and for ensuring that full records of any training provided are kept securely.

4.. General procedure

All personnel are to be trained in accordance with the Proskills National Prestressing Training Scheme or similar approved precast concrete scheme. The extent of the employee's training will depend upon their position held within the company.

5 Training

The training of personnel for safe stressing at all levels is to be carried out by Competent Persons or approved training organisations e.g. Proskills. They should be trained to Prestressing of Precast Concrete Training Certificate (PS1 to 6) as required, in conjunction with this Code.

Note: The need for re-training must be regularly monitored; this is an essential requirement for satisfactorily meeting the requirements of the current Regulations. Re-training requirements can be monitored by checking the expiry dates on certificates of achievement or by periodic assessment of individuals followed by refresher training. Training is the responsibility of the Company.

6 Certification/competency

Safe stressing training should be supported by training and competence in other tasks as appropriate:

- Crane operator
- Slinger signaller (NVQ or CPCS card required where overhead slinging is used in the factory).

- Forklift/ tele-handling driver training
- Lifting and handling
- Cut-off saw and abrasive wheel operation
- NVQ in precast concrete

In addition it is recommended that each team has either a suitably qualified person to administer emergency aid or a fully qualified First Aider.

APPENDIX B: National training scheme.

Prestressing of Precast Concrete, updated 2005.

Administered by Proskills UK Group

The original scheme was developed with the support of HSE.

The aim of the scheme is to identify and carry out training requirements specifically within the prestressing of precast concrete industry to defined standards.

Six modules are available for training of personnel involved with the activity of stressing. These modules are aimed at developing the skills and knowledge required to undertake the various roles within the stressing operations.

On-site training and assessment is carried out by accredited trainers, who are registered and certified by Proskills.

New or inexperienced personnel should not be permitted to engage in the prestressing of precast concrete unless supervised by a Competent Person.

1 Training and maintenance of training log

Only trainers deemed competent and approved by British Precast will be able to carry out the training and assessment of the training scheme.

Following the initial accreditation of the approved trainer, they will be continually monitored via a process of annual assessment. The trainers must demonstrate expertise in the following areas:

- Instructional competence
- Assessment competence
- Health and Safety competence
- Operational skills

The six modules are designed to develop the skills and knowledge required to undertake the various occupational roles identified within the operations involved.

The training modules identified as PS1 to PS6 cover the needs of Management/Supervisors, Maintenance, Bed and Stressing Operatives and all operatives who could be affected by the stressing activity.

- PS1 – Basic Health and Safety/General Stressing Awareness.
- PS2 – Maintenance of Stressing Equipment.
- PS3 – Receipt, Handling, Storage and Inspection of Stressing Wire/strand.
- PS4 – Bed Operative Procedures.
- PS5 – Stressing Operative Procedures.
- PS6 – Management of Site Safety in the Pre-stressing of Precast Concrete.

2 PS1 – General Stressing Awareness

This module is relevant to all personnel being trained, including office personnel or others who would benefit from the basic awareness of stressing. It can be used in isolation, and provides a general awareness of safety issues relating to work in a prestressing environment.

The topics covered:

- A background to prestressing
- Types of hazards associated with a prestressing operation.
- Types of hazards associated with prestressing production activities, both mechanical and non-mechanical.
- Danger of the exclusion zones.
- PPE.
- Risk assessments and safe systems of work.
- Safe access and egress.
- Warning signs, visual and audible.
- The Employer's duty of care.

3 PS2 – The Maintenance of Stressing Equipment (aimed at Maintenance Engineers, Foremen and Mechanics)

Whilst particularly relevant to maintenance personnel with a range of responsibilities in different factories, this module may be used with other groups.

This module is aimed at ensuring the delegate will be able to:

- Explain the hazards and risks associated with the tools and equipment and any substances used during the maintenance of the stressing equipment.
- Explain and demonstrate the isolation and lock-off procedures used within their particular operation.
- Understand the necessary safety checks laid down by the manufacturers' recommendations and the site procedures.
- Explain and demonstrate how to carry out the tasks associated with the prestressing activities, paying particular attention to the manufacturers' guidance and the relevant safe systems of work, including how to conclude the relevant tasks safely in line with standard operating procedures.
- Explain the relevant quality control requirements, including calibration.
- Be aware of and be able to complete any relevant records if required in line with:
 - Provisions and use of work equipment regulations (PUWER).
 - Control of Substances Hazardous to Health (COSHH).
 - The Personal Protective Equipment at Work Regulations (PPE).
 - The Management of Health and Safety at Work Regulations (MHSWR)

4 PS3 – Receipt, Handling, Storage, Inspection of Stressing Wires/Strands

This training module is normally relevant to all shop floor operatives and will ensure that anyone involved with the receipt, handling, storage and inspection of the stressing wires/strands will be competently able to:

- Undertake the relevant checks with regards to receipt of the wires/strands including the necessary paperwork and test certificates. Ensuring that each coil is identifiable. Having the ability to inspect the general condition of the coil and identify visually any defect or damage.
- Explain the risks and hazards associated with the safe handling of the coils, including the directional indicators. The storage of the coils to include the environment to which it may be exposed.

- Explain the safe system of work relating to the lifting and handling of the pre stressing wires/strands.
- Explain the safety checks required prior to lifting and handling of the prestressing wires/strands, ensuring that suitable lifting equipment is being used, that it has been tested, has the capacity to lift the wire/strand and be able to detect any defects through visual inspection.
- Explain the system used for the quarantining of any wire/strand that may be damaged, detecting wire/strand is that is unidentifiable, or shows the lack of paperwork, and checking the wire/strand general condition.
- Explain the storage system in place for stock rotation, the orientation of the coils, the environmental impact on the stock, the benefits of covered storage areas, the use of different types of storage systems i.e. racking or lobster pots.

5 PS4 – The Bed Operatives Procedures

This module will form the core of the training and will be suitable for casting and handling. The operative will understand the safety issues relating to a Bed Operative's duties and be able to carry out the operation safely. At the end of the module the operative will be able to:

- Identify the risks and hazards associated with the bed operation, including the importance of housekeeping, the use of machinery during the operation, other non-machinery hazards, and working on and around wires/strands with live loading.
- Understand wire/strand patterns, the different types of patterns and to read the wire/strand drawings showing the positions of the tendons and how to apply them.
- Understand wire/strand guides and pullers. The guides should be explained in depth covering the varying patterns for the product design. The operation and positioning of the wires/strands along the casting area and the preparation for the stressing to take place. The correct methods of coupling the wires/strands to the dead end and the live end of the casting area. The correct method for pulling the wires/strands from the coil and the directional issues. The importance of continual visual checking on the coils. The positioning of the wire/strand safety restraints and the reasons for their use.
- Fit barrels and wedges in the correct way, understanding the common issues with barrels and wedges and typical faults. Correctly store the barrels and wedges. The correct use of the barrels and wedges and the different types of wire/strand connectors. The methods used for effective separation of defect components. The need and use of grip release spray and the use of double-ended couplers.
- Understand how to fit button ends and the relevant faults and issues with them. The storage methods used for ferrules and their use requirements. The inspection of button ending equipment and the necessary tests. Be able to inspect the button end and the qualities required. The reason for not using grinding equipment on button ends and the correct method for cropping wires/strands before proceeding with the manufacture of the button end.
- Be able to identify where jointing of the wires/strands is required and know the correct operation of the wire/strand jointer and the issues to be aware of during the jointing.

6 PS5 – Stressing Operation Procedures

This module is to be completed in conjunction with PS4 by all operatives involved with the stressing activities.

The aim of this module is to provide Stressing Operatives with the relevant skills and knowledge for them to carry out the duties in a safe manner. It will cover the following points:

- The basic theory of prestressing ,in particular the methods of pre stressing used at the factory facility. Understand the meaning of prestressing load, extensions, and de tensioning.
- The different types of anchors used at the site.
- The ways of de tensioning by practical example.
- The risks and hazards associated with the pre stressing operations, the tools and equipment used in pre stressing, the working environment.
- An understanding by theoretical training and a demonstration all the equipment used during the prestressing activity.
- An understanding via demonstration the process, including pre-start, on-going, completion and de-tensioning.
- Calibration of the tools and equipment being used, the principles of calibration, the frequency and the responsibilities of the Stressing Operative.
- The responsibilities of the Stressing Operative and how to check that the equipment is suitable for use, the wires/strands are in the correct position and free from damage, the calibration of the equipment, ensuring that the equipment has been cleaned, is well maintained and in a serviceable condition.
- The dangers associated with and the preventative measures to be taken with wire/strand breakages, de tensioning, wire/strand slippage, and button end breakages.
- The importance of the near miss reporting procedures for the site.

7 PS6 – Management of Site Safety in the Prestressing of Precast Concrete

This module is an overview of site safety during prestressing operations and it aims to make managers appreciate the importance of training due to the complexity and the safety implications associated with the activities involved. The module is to ensure that Managers and Supervisors are adequately trained in the prestressing operations to allow them to recognise the safe working practices when using the associated work equipment, the risks which may arise and the necessary precautions.

The objectives of this module are to:

- Explain the Managers' responsibilities with regard to all the prestressing operations under the Management of Health and Safety at Work Regulations 1999. Also duties applied under the HASAWA 1974, PUWER, PPE, The Noise at Work Regulations, and COSHH.
- Explain the different types of stressing operations, stressing with jacks, stressing with hoist and Piab, multi-stressing.
- Explain the operational hazards at a prestressing facility.
- Explain the importance of an effective isolation and lock-off procedure.
- Understand the correct storage methods of both wire and strand.
- Explain the quality/traceability for prestressing wire and strand.
- Explain emergency plans and procedures in the event of the need to de-tension, audible and visual warning systems, power failure, suspect wire/strand procedure, isolation of materials.
- The benefits and requirements of the prestressing safety scheme.

8 Module assessments

The following methods of assessment will be used for each module:

PS1 – Observation and written multi choice questions

PS2 – Observation and written multi choice questions

PS3 – Observation and written multi choice questions

PS4 - Observation and written multi choice questions

PS5 – Observation, oral and written questions with a minimum pass mark of 90%

PS6 – Written questions with a minimum pass mark of 90%

9 Competency reviews

Before a recognised certificate is issued, the training of operatives for the activities must satisfy the requirements of practical and theoretical safety achievements tests for which training has been undertaken. This is a requirement for any new operatives and those who believe they have adequate and appropriate previous experience in the prestressing of concrete products.

10 Certification of Operatives

Certificates of training achievement will be issued to operatives who have complied with the training criteria and achieved the necessary standards that will qualify them for such a certificate. The certificate will be valid for three years after which a refresher practical and theoretical test will be undertaken to enable a renewal of the certificate.

Additional categories can be added to the skills certificate after the additional training has been completed satisfactorily.

For employees who only have the need for module PS1 – General Awareness, the certificate will be valid for a period of five years from the date of successful training completion. unless there have been changes on the plant or Legislation.

Renewals of the certificates will be subjected to a period of grace of one calendar month from the expiry date. Certificates not renewed within this time frame will be deemed to have lapsed.

APPENDIX C: Factory audit for safe stressing

An audit programme is being developed in conjunction with this Code to ensure that the safe working systems are being adopted and continue to be adhered to. The topics covered by a factory audit for safe stressing will include:

- Pre-site tour audit covering site documentation and maintenance of stressing equipment
- Stressing process and equipment
- Wires and strand.
- Wiring up the bed
- Barrels and wedges
- Stressing the beds
- Concrete casting
- De-stressing
- Removing barrels and wedges
- Training, certification and competence

APPENDIX D: Company stressing policy

General Policy

The following is a useful guide for companies with more than five employees, although written risk assessments and procedures are recommended in all situations where high-risk activities are undertaken.

All companies involved with prestressing activities should have a stressing policy that outlines the company procedures for all factories for safe stressing.

This should state that when tensioned, wire and strand contain a considerable amount of stored energy, which in the event of any failure of a wire/strand, anchorage or jack, may be released violently.

The risk of injury can be high if suitable controls are not maintained. To prevent incidents, Management and Personnel are responsible for ensuring the following policy and procedures are maintained.

The policy document should identify the reference documents, for example:

- This British Precast Code of Practice for the safe stressing of prestressed concrete products
- HSE Guidance note GS49 – Prestressed Concrete
- Health & Safety at Work Act 1974
- BS 8110 part 1: 1997
- BS 5896: 2012
- Existing procedures and documentation.

Company policy

The fundamental requirements of the policy are:

- All factories must have risk assessments documented for all stressing activities.
- All factories must have written production procedures that reflect their working routines.
- Only specially trained and authorised personnel will be allowed to carry out stressing activities. The Stressing Operative should hold a valid training certificate.
- The correct Personal Protective Equipment must be identified, available and worn.
- Stressing awareness training is required for all personnel who work on stressing or have cause to regularly work within stressing areas, whether actively taking part in stressing activities or other roles which require them to be in the vicinity of stressing operations.
- Stressing forces, extensions, calibration tolerances and load conditions must be documented by a Chartered Engineer.
- Prestressing equipment must be suitable for purpose, regularly maintained and calibrated with appropriate records kept, and used in accordance with the manufacturer's instructions.
- Cleaning and inspection of barrels and wedges and jack jaws must be carried out to a high standard with procedures to ensure worn components are replaced

- Procedures for the inbound deliveries of wire and strand, including the storage, record keeping, stock rotation and use of wire/strand, must be documented and training given to all relevant personnel.
- Procedures for the setting up of stressing beds must be in place, including the running of wire/strand, cutting and placing them into the stressing bed, and the guarding of the bed, including the use of safety chains or other suitable wire/strand restraint systems.
- Documented procedures for the receipt, storage, cleaning and maintenance of barrels and wedges must be in place and trained out to relevant personnel. This is to include procedures for ensuring stock rotation and identification of types of barrels and wedges to prevent misuse.
- Stressing procedures and safe systems of work must be in place for the stressing operations undertaken and they must be relevant to the type of stressing activities. This must include fitting barrels and wedges to wire/ strand, extension checks, guarding as well as documented procedures in relation to crossed wires/strands or other non-routine operations.
- Procedures for the de-tensioning of beds must be available and these should take into account concrete strength and removing of barrels and wedges from wire or strand.
- Maintenance procedures must be created and training given for any activities where prestressing equipment is to be serviced, maintained etc.
- Information must be available to enable operational management to ensure all relevant personnel are trained to the necessary standards to enable them to carry out their work activities safely. These procedures must document training frequency, refresher training, competency reviews and certification for operatives.

The risk assessments together with any other guidelines must be taken into account when writing the safe systems of work and the procedures for the production manuals for each factory.

Should any changes be made to production routines within the factories e.g. new equipment, new working practices etc., then the risk assessment, the safe system of work and the production procedure must be reviewed, operatives re-trained and the appropriate changes made to the documented procedures.



British Precast

The Old Rectory

Main Street

Glenfield

Leicester

LE3 8DG

Email: info@britishprecast.org

Web: www.britishprecast.org

