Flat slab construction is among the most efficient methods of construction, enabling a consistent head space (i.e. a flat soffit) to be achieved across the entire floor with the resulting benefits of easier layout of services and reduced overall floor-to-floor heights.

The challenge faced by engineers is that the weight of the slab is supported directly on a column. This creates concentrated localised shear stresses which, without the necessary reinforcement, could result in the slab ‘punching’ through the column.

One way to overcome this is through the use of enlarged columns, column capitals/drop heads or a localised increase in slab thickness. However, these approaches not only disrupt the otherwise flat soffit and reduce floor space, but can also require complicated formwork. This minimises the benefits of this form of construction.

The usual solution therefore is to install shear links within the slab around the top of the column, which locally increases the shear resistance of the slab and safely transfers the shear load from the slab into the column. While effective, these are extremely time-consuming to install, design and detail and are also difficult to check for position and quantity.
Shearail® is a CARES and BBA approved prefabricated punching shear solution which increases the shear resistance of a slab and safely transfers the shear load from the slab to the column.

Supplied to site as ready-made rails, instead of individual links or studs, it offers the convenience, speed and quality assurance of a prefabricated system and is easily designed and detailed using Max Frank’s free design service or calculation software which generate a layout drawing for inclusion within the building plans.

Shearail® is manufactured from UK CARES approved materials under a CARES certified BS EN ISO 9001:2008 Quality Management System, providing Consultant Engineers, Contractors and Local Authorities with the assurance that the material is from a traceable source and has been independently tested and verified for use in concrete floors in accordance with appropriate BS and BS EN standards.

Shearail® delivers confidence in its performance and ensures peace of mind.
The Shearail® System

Shearail® is a prefabricated punching shear reinforcement system for concrete slabs and increases construction speed, improves build quality, minimises dependency on skilled labour and significantly reduces on-site costs. Similarly Shearail® can be used where practical to replace traditional links in beams, rafts, etc.

Shearail® double headed studs are at least equal to and, in most cases, better in performance than traditional shear links due to the improved end anchorage of the heads as compared to the bond anchorage of links.

This improved end anchorage controls the shear crack width and therefore enhances aggregate interlock between the two shear faces. When double headed studs are used in flat slabs with continuous top and bottom reinforcement over the column, this also improves the ductility and therefore the shear force at which the diagonal shear crack forms.

Similar to traditional shear reinforcement, the headed stud works as a vertical tie between the top tension and the bottom compression chord in the strut and tie model of the slab. Unlike traditional shear reinforcement, this system is more efficient because the stud heads form a positive end anchorage flush with the top layer of tension reinforcement, whereas the anchorage of links/stirrups are based mainly on bond.

The key factor determining the performance of the stud is the ratio of three: the head diameter to the shaft diameter for hot forged studs. This will allow the minimum characteristic strength of the material to develop to at least 500 MPa as stated in BS 8110 part 1 and BS EN 1992-1-1 (EC2).

When comparing links with conventional studs, research has shown that any additional material costs incurred when purchasing a prefabricated punching shear system, such as Shearail®, are generally far outweighed by the savings from a significantly reduced fixing time; the Shearail® system being up to ten times quicker to install.

Shearail® offers the convenience, speed and quality assurance of a prefabricated system.
Shearail® studs are manufactured from UK CARES approved grade B500C ribbed carbon steel reinforcing bars with yield strength of 500 MPa.

The stud material is specially sourced and selected to meet the sufficient temperature involved to forge the heads and grain refinement resulting from the thermal cycle and the deformation process. The finished products are regularly tested and inspected.

The bars are forged to produce double headed studs in a controlled factory environment whilst maintaining the original characteristic yield strength of the steel, and more importantly, the ductility values.

Rails are manufactured to the specific requirements of the design in accordance to BS 8110 and BS EN 1992-1-1 (EC2) determining the stud diameter, layout patterns, spacing and number of studs.

Shearail® double headed studs, being at least equal to traditional shear links, can replace the links on a like for like basis.

Studs are available in various diameters and lengths to suit most slab depths. Each stud is welded to a non-structural carrier rail at predetermined centres according to the specification, in most cases the rails are symmetrical and can be placed either way round on site.

The finished rails are individually labelled with the floor level, column location and palletised ready for site delivery.

The design methodology is determined by BS EN 1992-1-1-2004 (EC2) incorporating the UK National Annex or to BS 8110-1:1997. Max Frank have in-depth design manuals that cover most conditions encountered and design programs to assist the Project Engineer to achieve a practical design and rail layout. Max Frank also offer in-house designs prepared by a dedicated technical team.
Shearail® is independently tested and certified to the highest standards to enable customers to have complete confidence in its quality and suitability.

All elements and processes are carried out under a CARES BS EN ISO 9001:2008 Quality Management System from material purchasing to packing & labelling with the completed operation being carried out in one location aiding material traceability and reducing any possibility of misunderstanding.

All processes are independently audited by the BRE & UK CARES on a six monthly routine surveillance; each material batch is independently tested to the original material certificates supplied, no end offcut material is ever used for consistency.

Full traceability to the steel mill is in compliance with BS 4449:2005 directly for each element.

Unlike some rails on the UK market today we do not just certify assembly of third party elements - every process, operation and purchase of raw material is audited.
Service & delivery

Our design service enables us to accurately estimate project costs and speedily provide quotations.

In addition to this service, Max Frank also provide design software for clients who prefer to produce their own calculations and layouts in-house. (Please see the following pages for full details of these services).

Max Frank provide a full customer support service for Shearail® projects – from application advice, through to provision of both proposal and working drawings, to onsite support.

Design Service

Delivery & Support

On receipt of your purchase order, we will agree delivery schedules to meet your onsite program and ensure access or time restrictions are considered. Standard delivery normally takes four to seven working days but we know that sometimes a situation on site can catch you out, so you may wish to consider our express delivery service (please call us to discuss your requirements).

Our project coordinators will keep you up to date with a stream of information regarding all stages of delivery. Your personal project timetable will also be available to show a log of all Shearail® deliveries completed and projected.
The design methodology is determined by BS EN 1992-1-1-2004 (EC2) incorporating the UK National Annex or to BS 8110-1:1997. Max Frank have in-depth design manuals that cover most conditions encountered and design programs to assist the Project Engineer in achieving a practical design and rail layout. We also offer in-house designs prepared by a dedicated technical team.

An EC2 design will normally produce a radial or cruciform layout pattern, however square patterns can also be achieved following certain procedures with the basic design principles below being maintained.

Outline design procedures for a suspended slab:

1. The direct shear at the edge of the loaded area (column or pile) is checked and satisfied.

\[ \frac{V_{Ed}}{V_{Rd,max}} \leq u_o \text{ perimeter must be calculated in accordance with EC2} \]

2. The punching shear stress at the control perimeter \( u_1 \) is determined; if it's within the concrete punching stress resistance no punching reinforcement is required and no further action is required.

\[ \frac{V_{Ed}}{V_{Rd,c}} \leq u_1 \text{ perimeter is 2d from loaded area in accordance with EC2} \]

3. If the concrete stress is exceeded, punching shear reinforcement can be added to increase the effective resistance of the slab. If the limit is exceeded the slab properties should be increased accordingly.

\[ \frac{V_{Ed}}{V_{Rd,c}} > 2 \]

(It may be possible to increase this to 2.5 \( V_{Rd,c} \) established from full scale test plus an independent report. This is at the discretion of the Project Engineer. It is normal practice is to remain within the set limits applied in EC2)

4. Perimeters of punching shear reinforcement are required to within \( kd \) (1.5 x the effective depth) of where the normal reinforced slab is able to resist the applied shear loads (\( U_{out} \)).

\[ A_{sw} = \frac{\left( V_{Ed} - 0.75 V_{Rd,c} \right) u_1 s_j}{(1.5 V_{Rd,c} \times \text{number of studs})} \]

or

\[ A_{sw,min} = (1.5 / \{ s_j \}) \times (0.08 \sqrt{f_{cd}} / f_{yd}) \]

The calculated value is for the area of one stud, the reinforcement is projected out to within \( kd \) (1.5d) of the \( U_{out} \) perimeter.

Max Frank have comprehensive design manuals that are updated to the latest amendments of the design codes available on request, in addition to free design software that show full line by line calculations.
It may be possible to increase stud spacing to 3.5d behind 2d from the column face, this is at the discretion of the Project Engineer established from independent full scale testing, however it is normal practise is to remain within the set limits applied in EC2.

Note: The value of k for use in a Country may be found in the National Annex (normally 1.5).

Orthogonal Shearail layout Pattern

Links are replaced by studs on a like for like area basis.

Note: the studs indicated in blue are not used in the punching shear design.

Traditional link layout as designed by the Project Engineer in accordance to the Concrete Eurocode 2, published by the Concrete Centre.

Note: the links indicated in black are not used in the punching shear design.
Design Method
& Detailing Requirements BS 8110

Shearail can be designed into the slab using the same design principles as for shear links and in accordance with BS 8110 part 1.

The concrete is first checked for shear at the column face against allowable limits from the code and is then checked along a perimeter at a distance of 1.5d from the column face. If shear reinforcement is not required, then no further checks are necessary. If shear reinforcement is required then the concrete is checked along subsequent further perimeters 0.75d apart until no further shear reinforcement is necessary.

The area of reinforcement required at the first perimeter (1.5d) is then split by placing at least 40% at 0.5d from the column face and 60% at 1.25d from the column face. If subsequent areas of reinforcement are required, these are spaced at 0.75d from the last perimeter of reinforcement.

Two perimeters of studs are used for the calculation of the area required.

<table>
<thead>
<tr>
<th>Condition</th>
<th>No moment being considered</th>
<th>Moment being considered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal</td>
<td>1.15V₁</td>
<td>V₁(1+1.5M₁/V₁ₓ)</td>
</tr>
<tr>
<td>Edge (bending about an axis parallel to the free edge)</td>
<td>1.25V₁</td>
<td>1.25V₁</td>
</tr>
<tr>
<td>Edge (bending about an axis perpendicular to the free edge)</td>
<td>1.4V₁</td>
<td>V₁(1.25+1.5M₁/V₁ₓ)</td>
</tr>
<tr>
<td>Corner</td>
<td>1.25V₁</td>
<td>1.25V₁</td>
</tr>
</tbody>
</table>

1. Design at the Column Face

a. Calculate Design Effective Shear (Vₑeff)

When calculating Vₑeff the factors shown in the table above are applied to design shear load (V₁).

**Please note** – When considering moments, both axes of the column should be checked and the worst case Vₑeff used.

b. Calculate Maximum Design Shear Capacity (Vₑmax)

\[ Vₑmax = \frac{Vₑeff}{f_c} \]

This should not exceed a maximum value of 0.8f₂₅ or 5 N/mm², whichever is the lower.

2. Design at the Perimeters

a. Calculate Design Concrete Shear Stress (vₑ)

\[ vₑ = 0.79 \left( \frac{100A}{b_d} \right)^{1/3} \left( \frac{400}{d} \right)^{1/4} \left( \frac{f₂₅}{25} \right)^{1/3} \]

1.25

where

\[ \left( \frac{100A}{b_d} \right)^{1/3} \text{ not to be taken greater than 3} \]

\[ \left( \frac{400}{d} \right)^{1/4} \text{ not less than 0.67 or less than 1 for slabs greater than 400mm deep} \]

\[ f₂₅ \leq 40 \text{ N/mm²} \]
b. Check Design Shear Stress ($v$) at First Perimeter (1.5d)

$$v = \frac{V_{ed}}{u_d}$$

If $v \leq v_c$ no punching shear reinforcement required.
If $v_c < v \leq 2v_c$ punching shear reinforcement required.
If $v > 2v_c$ the slab is not sufficient. Adjust slab/column parameters.

c. Calculate the Area of Steel Required ($A_{sv}$)

If $v \leq 1.6v_c$ then

$$A_{sv} = \frac{(v - v_c)}{0.87f_{yw}}$$

If $1.6v_c < v \leq 2v_c$ then

$$A_{sv} = \frac{5(0.7v - v_c) u_1 d}{0.87f_{yw}}$$

These must not be less than the minimum steel of

$$\frac{0.4u_1d}{0.87f_{yw}}$$

$$f_{yw} = 500 \text{ N/mm}^2$$

d. Check Subsequent Perimeters

Repeat steps (b) & (c) but using $u_1, u_2, u_3$ etc. until $v \leq v_c$. 
Shearail® link conversions

Where shear links have already been designed, they can be quickly and easily converted and replaced by Shearail® to comply with the original design.

The areas provided in each perimeter with Shearail® will be at least the area provided by the links. These conversions can be carried out either by using the link drawings or using the output from the RCC spreadsheets.

Double headed shear studs are now a generic method, being used fifteen years in the UK and over thirty years in Europe.

Numerous independent tests have demonstrated the stud heads form positive end anchorage flush with the top layer of tension reinforcement. Whereas the anchorage of links is based mainly on bond, the improved end anchorage of the Shearail® stud controls the shear cracks and enhances the aggregate interlock.

Link conversions; EC2

Shearail® from Max Frank is a BBA and CARES approved punching shear solution

Equivalent arrangement using 24 no. 20mm diameter, 3 stud Shearail® rails.
Shearail® offers many advantages over loose shear links which can be time consuming to design, detail and install. Shearail® is up to ten times faster to install and easier to check for correct positioning.

Link conversions; BS 8110

Equivalent arrangement using 20 No. 14mm diameter, 4 stud Shearail® rails.
Shearail® installation

When installing Shearail® on site, the rails can be fitted as follows:

**Bottom up (recommended)**
1. Rails are fitted first by spacing the rails off the formwork using concrete spacers and nailing to the formwork through the carrier rail and spacer.
2. The bottom and top rebars are then laid in the usual manner around the Shearails.

**Top down**
1. The top and bottom rebar is fitted as per usual.
2. The rails are then placed through the rebar with the carrier rails sitting on top of the T1. These are then securely wire tied to the rebar so that when the concrete is poured, they do not move.

If the rails when fitting sit on the T2 then these need to be spaced up so they are level with the top of the T1. Special Shearail® supports are available on request.
Max Frank Ltd. provide a full customer support service for Shearail®.
Max Frank provide a free design service to assist in the design and detailing of Shearail® into your project.

To benefit from Max Frank’s Shearail® design service simply email your drawings to shearail@maxfrank.co.uk. Our experienced and dedicated Shearail® technical department will use their expertise to formulate the optimum concrete reinforcement strategy for your project based on the drawings and information supplied by you.

You will receive a quote prepared by our in-house costing team who will liaise with the design engineer dealing with your enquiry.

Our design service will provide full calculation sheets for your approval and can also supply DXFs for inclusion in your CAD drawings.

To enable us to proceed with a design we would require the following information:

- General Arrangement (G.A)/Layout of the floor being considered and the floor below
- Top reinforcement drawings (Bottom if transfer situation)
- Any drawings showing voids not detailed on G.A/Layouts
- Any applicable sections (steps etc.)
- Shear loads (kN) and any moments to be considered (kNm), (factors from the code will be applied if only unfactored loads are supplied)

The Shearail® design software represents a huge step forward in the design and detailing of our leading CARES and BBA approved prefabricated punching shear reinforcement system.

The free of charge Shearail® Design Program enables you to design Shearail® layouts to BS 8110 and EC2 easily and simply. It also allows you to convert existing link designs to an equivalent Shearail® layout.

The program provides you with fully checkable calculations/conversions and also includes a DXF out facility so the layouts created can easily be included in your drawings.

The EC2 program is the first standalone program of its kind in the UK and delivers a whole raft of new features. Easier to use and, with a new graphical interface, it virtually eliminates the need for a separate CAD program.

Draw voids, trim and move rails, edit layouts directly in the program, and your calculations are automatically updated.

And instead of having to file all your calculations in a single folder, you can now save them to the project folder of your choice.

The Shearail® Design Program enables you to design Shearail® layouts to either BS 8110 or EC2.
Our free Shearail® design program is also available to download from our website.

More **functional** for the designer

Our free of charge software enables easy and simple design to either BS 8110 or EC2 standards. Whilst the BS 8110 program provides for you to convert existing link designs to an equivalent Shearail® layout, the EC2 version delivers a number of additional benefits to designers.

**Simple integration with your project file structure**
- Save calculations wherever you like: a project folder, a server or a memory stick
- Assign different locations for each calculation

**Intuitive graphical interface**
- Edit layouts directly in the program
  - no CAD required
- Produce print out based on actual layout
  - no need for additional drawings
- Dramatically simplified calculations
- Draw voids directly into the program
  - no need to redraw in CAD
- Calculations are automatically updated with any change to layout

**Enhanced capabilities**
- Add or remove calculations and projects quickly and easily

To download a copy of the program please visit [www.maxfrank.co.uk/shearail-software](http://www.maxfrank.co.uk/shearail-software)

Alternatively contact us via [technical@maxfrank.co.uk](mailto:technical@maxfrank.co.uk) or phone 01782 598041 to request a CD version.
Shearail® in use

Greenwich Reach, London

University Hospital of North Staffordshire, Stoke-on-Trent

The Shard, London

Velocity Tower, Sheffield

Bond Street Station, London

5 Broadgate, London
The Reinforcement Specialists

Punching Shear Reinforcement ‘an effective solution’

Punching shear failure is a catastrophic brittle type failure which occurs at the flat slab-column junction. This presentation covers the problem of slabs ‘punching’ through the column and how it can be prevented.

The seminar usually lasts 45 minutes, with a question and answer session at the end. Max Frank will be happy to cover the cost of refreshments.

The following points are covered:
- Punching Shear - the problem
- Generic systems and installation
- Shearail® punching shear reinforcement
- Approvals, testing, time and cost saving
- Design to BS 8110 and EC2
- Shearail® design software

Shearail®
Shearail® prefabricated punching shear reinforcement system, CARES Approved to EC2 and BBA Certified to BS 8110 and EC2 for flat, piled and post-tensioned slabs.

Egcobox®
BBA certified system for preventing thermal bridging between cantilevered components i.e. balconies, walls and the building frame.

Egcodorn®
High-performance corrosion-proof transverse shear force dowel systems that can accommodate most static and dynamic loads.

Tubbox®
The simple fast and cost effective way to produce concrete columns on site.

Spacers
Standard and premium spacers: single block, bar and special spacers manufactured from extruded fibre-reinforced concrete.

Max Frank on-line
Scan this QR code to access a wealth of information and resources at www.maxfrank.co.uk

Also from Max Frank
- Pecafil® permanent formwork
- Pecavoid® ground movement solution
- MFL Void Former & Sheet Pile Infills
- Stremaform® jointing formwork
- Sealing Strips & Waterstops
- Formwork Liners

Please note that all calculations provided are preliminary and supplied in good faith for information only. Due to the nature of the design process, the overall responsibility rests with the Project Engineer. We reserve the right to amend specifications without prior notice. Whilst the data contained in this brochure is true and accurate to the best of our knowledge at the time of publication, all liability for error and omissions, or any resulting loss or damage, however caused, is hereby excluded. © Max Frank 2014.