PFEIFER

# General Technical Introduction to PFEIFER Lifting Anchor Systems

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## 1. Definition

The term “Lifting Anchor System” refers to a complete system which makes it possible to attach and lift precast concrete units. It consists of the PFEIFER Lifting Anchor that is to be cast in the concrete unit, e.g. Waved Anchor or Socket – the corresponding unmistakably identifiable lifting device, e.g. Swivel Eye or Lifting Loop – the necessary accessories – Formwork Disc, Fixing Bolts – and Installation Instructions which cover all the user’s questions with edge distances and lifting restrictions etc.

With this sort of system the user has everything he requires from one source and is consequently able to safely move precast concrete units during lifting, transport and assembly.

## 2. Selection of Lifting Anchor Systems

Due to clients’ increased architectural demands there is such a variety of precast concrete units that one system alone cannot cover all needs. Therefore, PFEIFER has three fundamentally different lifting anchor systems in the programme.

These systems are the **PFEIFER Thread System**, the **PFEIFER BS Anchor System** and the **PFEIFER WK System**.

These three Lifting Anchor Systems are described in detail in the following “General Installation Instructions” for the PFEIFER Thread System”, the “General Instructions for the PFEIFER BS Anchor System”, the “General Instructions for the PFEIFER WK System and the respective product data sheets.

Fortunately, despite the variety in shapes in precast concrete unit construction, the basic forms that are decisive for selecting lifting anchors can be simplified as follows:

– Thin-walled panels which have to be attached on the head side (Table 1, column 1).
– Voluminous plate elements, such as floor slabs for industrial construction, which may later possibly be reinforced with cast in-site concrete (Table 1, column 2).
– “Flat elements, such as floor slabs, for house situ building, which may later be reinforced with in situ concrete (Table 1, column 3)”.
– Solid, heavy elements such as foundation footings, manhole covers, heavy beams (Table 1, column 4).
– Delicate linear elements, such as slim coloumns and beams which are attached in their quarter points or on the top side (Table 1, column 5).

It is ultimately the customer’s decision, based on the technical conditions as well as the fundamental calculations in the catalogue received, which lifting anchor is to be used for which individual application. Some typical individual applications with lifting anchor recommendations are specified in the above-mentioned table 1 “Examples of Applications for PFEIFER Lifting Anchor Systems.”

In this “General Technical Introduction” to PFEIFER Lifting Anchor Systems, the user is provided with theoretical know-how so that he is able to select the right lifting anchor and calculate it.

In the event of special installation cases, it is possible for the user to receive an individual proposal for the installation prepared by the experienced and qualified PFEIFER technical consultants at our branches. In particularly difficult cases, the engineers in the technical department in the headquarters in Memmingen are also available to give advice to customers with problems.

## 3. Formal Conditions for the Use of Lifting Anchor Systems

The construction employers’ liability insurance association is responsible for monitoring industrial safety in the building industry and the quarry employers’ liability insurance association is partly responsible for precast concrete factories. **”Safety Regulations for Lifting Anchors and Lifting Anchor Systems for Precast Concrete Units”** has been issued by the main association of the trade employers’ liability insurance association.

The Safety regulations constitute the currently generally acknowledged state of technology, as there is no other set of rules and regulations concerning the lifting of precast concrete units (in Germany).

The fulfilment of the requirements of the **“Safety Regulations for Lifting Anchors and Lifting Anchor Systems for Precast Concrete Units”** by PFEIFER lifting anchor systems is briefly described below using key words:

– **Term: Lifting anchor system, consists of lifting anchor plus lifting device (§ 2.2)**
  PFEIFER Thread System: PFEIFER Anchor Socket, PFEIFER Waved Anchor and PFEIFER Lifting Loop (Figure 1) or PFEIFER Swivel Eye (Figure 2) as well as accessories.
  PFEIFER BS Anchor System: PFEIFER BS Anchor and PFEIFER BS Hook as well as accessories (Figures 3 and 4).
  PFEIFER WK System: PFEIFER WK/DR Anchor and PFEIFER Quicklift as well as WK Moulding Insert (Figure 5)
– **Only complete lifting anchor systems are admissible (§ 5.2).**
  The user may only use original parts that belong together from the PFEIFER Systems. The combination of articles from various manufacturers is not admissible due to the large risk of technical incompatibility.
– **Lifting devices according to UVV VBG 9a (§4.1.1)**
  PFEIFER Swivel Eye, Lifting Loop, BS Hook and Quicklift correspond to the Safety regulations. Requirements:
  Wire rope $\geq \geqq 6$ mm
  No. of wires (DIN 3088): $\geq$ up to 14 mm at least 114 individual wires
  $\geq$ 14 mm upwards 200 individual wires

Rope swaging according to DIN 3093
Ductile materials with high elongation at breaking point.

**Figure 1**

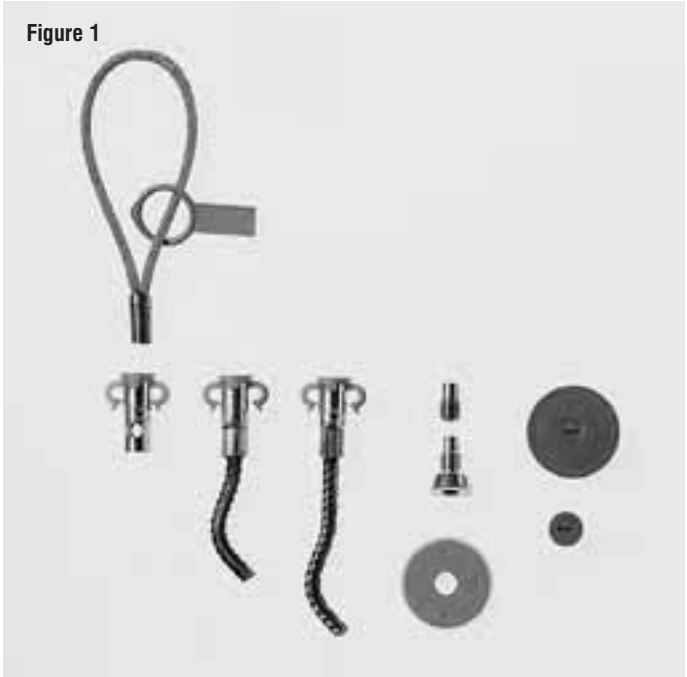


**Figure 2**

Figure 3

Figure 4

Fulfilling these technical specifications by using quality steel wire ropes which are partially specifically manufactured for these purposes is a matter of course for products such as PFEIFER Lifting Loops or PFEIFER BS Lifting Anchors at PFEIFER Seil- und Hebetechnik GmbH, who have been a renowned manufacturer and processor of rope for many years.

– **It must be possible for screw openings to be sealed off from dirt and concrete slurry (§ 4.5.3)**

PFEIFER's Accessories such as Fixing Bolts or Button Head Fixing Bolts safely prevent dirt and concrete from penetrating. Large and small PFEIFER External Caps protect the thread from moisture and dirt.

– **Quality assurance (§ 7)**

Continuous quality monitoring by the manufacturer is necessary.

In order to guarantee the quality of PFEIFER's Lifting Anchoring Systems, quality monitoring is carried out according to a quality assurance system. The quality check covers all phases of the manufacturing process, starting from the goods inward inspections and manufacturing monitoring to the goods outward inspections. Parallel to the manufacturing, samples are tested by means of tensile tests in PFEIFER's own testing laboratory with tensile testers of up to 600 t. In addition, the accuracy of the pressing length, the diameter, the thread accuracy, the thickness of the corrosion prevention coating etc. are permanently tested.

– **Installation and use according to installation instructions (§ 5)**

Consideration of all load influences
Fully screw in screw parts
Rope loops that are cast in concrete are not for repeated use
Discarding time for wire rope products

It is necessary here for the user of PFEIFER Lifting Anchor Systems to observe the unique PFEIFER Installation Instructions in their entirety.

– **The installation instructions must include (§ 4.2.1):**

Load capacity
Conditions for installation and use
Load cases und restrictions
Minimum edge and axis distances
Thickness of components.

– **Data for concrete compressive strength 15 N/mm² (§ 4.2.2)**

PFEIFER includes all the technical details and specifications in the installation instructions and product data sheets for each product. The PFEIFER catalogues and installation literature have been regarded as the best and the most complete of their kind for many years.

– **Identification (§ 4.3)**

Attached securely to anchors
Load capacity, type, manufacturer
Visibility when cast in concrete

Due to the PFEIFER Threaded Sockets being roller embossed as well as the PFEIFER Data Clip and the load capacity identification tag, every sort of identification is available and can even be read when cast in concrete. Furthermore, PFEIFER colour coding (one colour per load capacity level) provides additional safety and makes handling in the precast factory and during assembly considerably easier.

– **Design of the Lifting Anchor Systems is carried out by the manufacturer (§ 4.4)**

Safety of allowed anchor capacity (= safe working load) compared to plastic deformation: 2 times
Safety of allowed anchor capacity (= safe working load) compared to breakage of the transport anchor: 3 times
Safety of allowed anchor capacity (= safe working load) compared to concrete breakout: 2.5 times
Safety of allowed anchor capacity (= safe working load) compared to minimum breaking strength of steel ropes in lifting anchor systems: 4 times

As a result of appropriate calculation and design, these values are easily obtained with PFEIFER Lifting Anchor Systems not only with the lifting anchors but also with lifting devices. Permanent quality inspection with tensile tests that are carried out parallel to production is constant proof of this. Corresponding test certificates can be produced. The employer's liability insurance association as well as the University of Stuttgart have checked the values and have confirmed them for all PFEIFER's Lifting Systems.

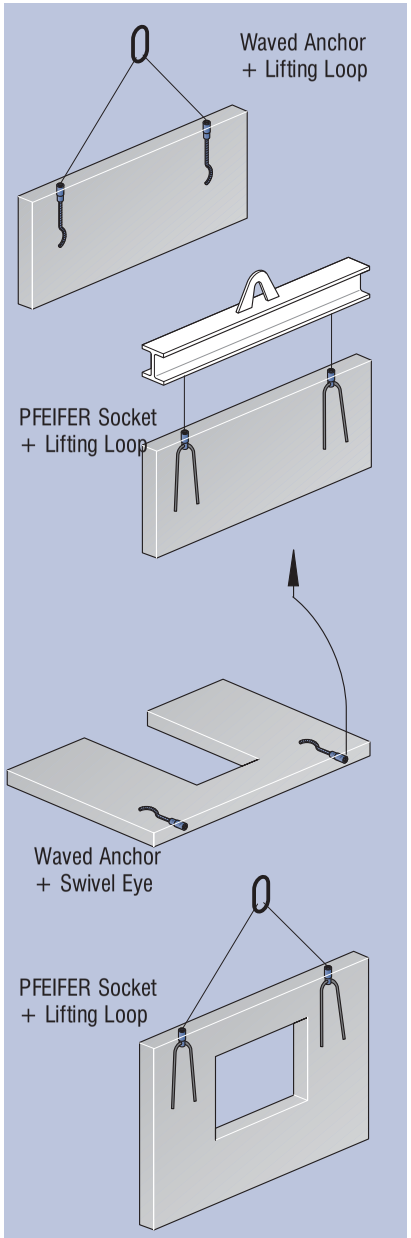
– **Pull out test (§ 6)**

Pull out test for each anchor type, anchor size, load case Inspection by a material testing institution for the pull out test, that 2.5 times as much safety from concrete breakout exists for each load case. Concrete compressive strength 15-25 N/mm², back calculation to 15 N/mm².

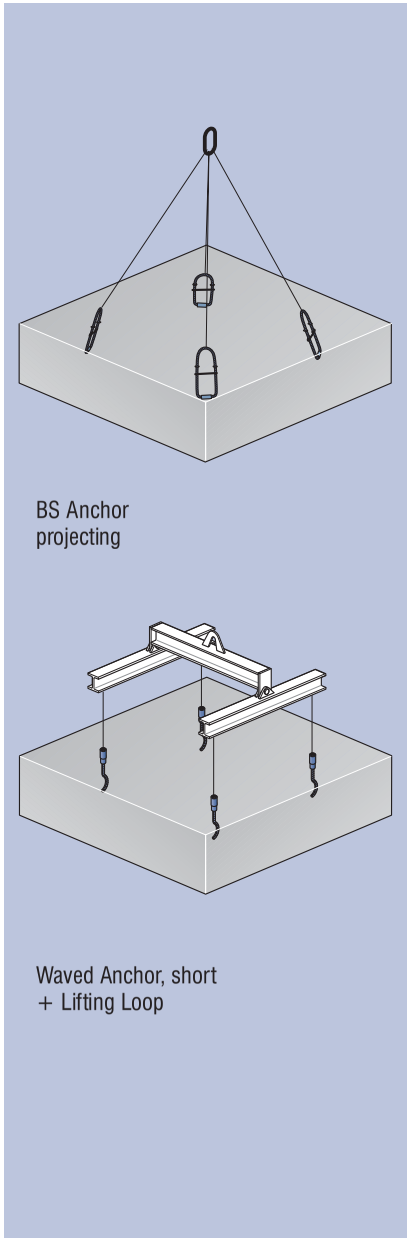
Figure 5

# Table I – typical applications of PFEIFER Lifting Anchors

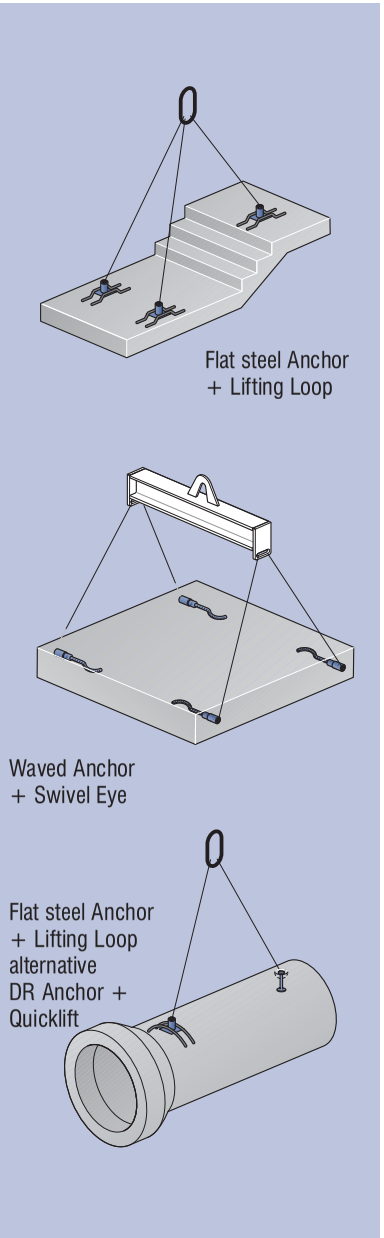
## 1 thin wall elements



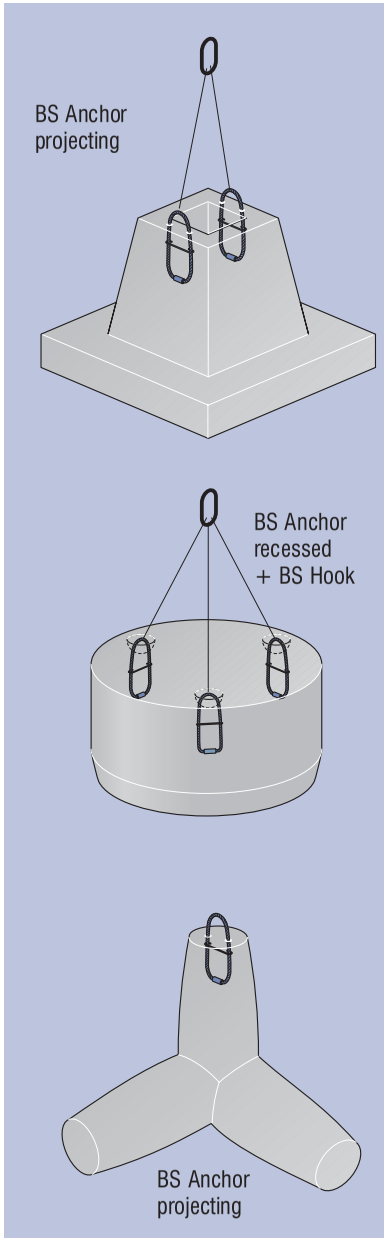

## 2 voluminous elements



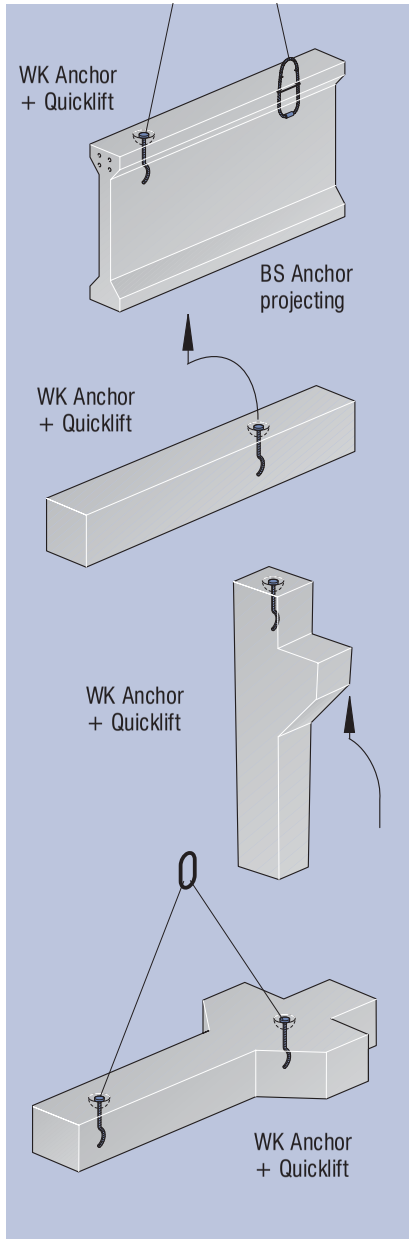

## 3 Flat elements, pipes




## 4 heavy elements




## 5 columns, beams



In a large series of experiments, Prof. Dr.-Ing. Eligehausen from the Institute for Construction Materials at the University of Stuttgart carried out pull out tests in which it was possible for PFEIFER Lifting Anchors to demonstrate their high stage of development.

## 4. Design calculation of Lifting Anchor Systems

The criteria for the selection, design calculation and arrangement of the PFEIFER Lifting Anchors in the precast concrete unit are safety, economy and easy handling for manufacture and erection of the precast concrete units. All lifting anchors are to be dimensioned by engineers in accordance with anticipated forces during use. During this procedure the following criteria are to be taken into account:

- **Dead weight of the precast concrete unit.**
- **Adhesion of the concrete unit in the formwork**
- **Acceleration forces during crane operation**
- **Geometric arrangement of the lifting anchor in the precast unit**
- **Statically undetermined suspension.**
- **Parallel shear pull for multiple-legged slings.**
- **Transversal pull when erecting horizontally positioned panels.**
- **Concrete compressive strength during lifting.**

The above mentioned criteria for the correct design calculation of Lifting Anchor Systems will be explaned in detail below:

### 4.1 Dead Weight of the Precast Concrete Unit

For normal reinforced concrete units a specific weight of $\rho = 25$ kN/m$^3$ is assumed. This formula is used to calculate the dead weight G with the volume V of the precast unit in the following way:

$$G = \rho \cdot V \qquad (1)$$

### 4.2 Adhesion of the concrete unit in the formwork

The formwork adhesion depends on two factors:

1. The consistency of the formwork's surface. The values in Table 2 apply here.
2. With a rough structured formwork, the values can amount to double and more than those that result from the adhering formwork surface (A). Formwork surfaces which are removed before lifting are not included in the calculation.

**Table 2 – Standard values for formwork adhesion**

| Type of formwork | ha |
|---|---|
| Oiled steel formwork | 1 kN/m$^2$ |
| Wooden formwork, smooth surface | 2 kN/m$^2$ |
| Wooden formwork, rough surface | 3 kN/m$^2$ |

Consequently, the formwork adhesion force is Ha:

$$Ha = ha \cdot A \qquad (2)$$

Friction on vertical formwork components should be avoided, as the forces are difficult to quantify.

**Table 3 – Acceleration factors**

| Lifting device | | Acceleration load factor f |
|---|---|---|
|  | Tower cranes for building work (H1) | f = 1.1–1.3 |
|  | Mobile cranes (H2)<br>Heavy duty mobile cranes (H2) | f = 1.2–1.6<br>f = 1.1–1.3 |
|  | Loading bridges, Gantry cranes (H2) | f = 1.2–1.6 |
|  | Excavators, According to operation | f = 1.6–2.5 |
|  | Fork-lift truck | f = 1.6–3.0 |

By removing as many formwork parts as possible before lifting, the adhesion of the concrete unit in the formwork should be minimized.

### 4.3 Acceleration Forces during Lifting

Additional forces are mobilized by lifting, swivelling, moving and setting down a precast concrete part by crane. This is because inertia effects are involved. The greater the acceleration, the greater the forces. Therefore, an acceleration load factor f, see Table 3, is to be used, which is multiplied by the weight of the precast concrete unit.

For a conventional crane in a precast factory with a slow hoist, it is realistic to assume a value between f = 1.1 and f = 1.3.

**Caution is recommended when lifting and transportation with excavators on uneven surfaces; it is adviseable to assume at least the factor f = 2.**

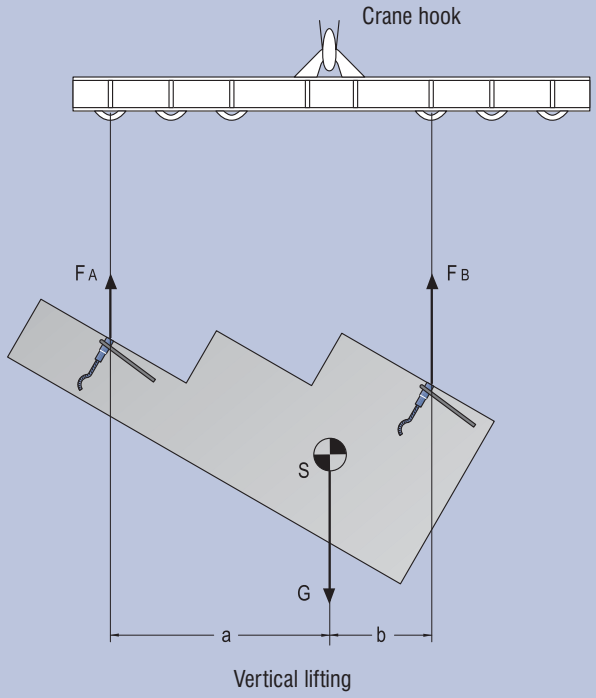
### 4.4 Geometrical arrangement of the lifting anchors in the precast concrete unit

A load always swings with the centre of gravity vertical below the crane hook.

If the anchors are arranged symmetrically to the centre of gravity and if, for example, a statically determined suspension is ensured by suspension equipment with balancing device and if the length of the slings is equal in all legs, then the anchor forces are equally great.

If symmetrical arrangement to the centre of gravity is not possible, the precast concrete unit will rotate when lifted until the centre of gravity comes below the hook (see Figure 6). If the centre of gravity is situated within a surface that is

**Figure 6**




Vertical lifting

**Asymmetrical anchor arrangement**

circumscribed by the anchors, then all the anchors will bear the load, however to different degrees. In simple cases, the different anchor forces can be calculated by two anchors on the head side or by three anchors on the surface of a panel. For this purpose, point 4.5 must be taken into account.

For 2-sling set this is shown:

$$F_A = \frac{G \cdot b}{a+b} \qquad (3)$$

$$F_B = G - F_A \qquad (4)$$

If the centre of gravity is situated beyond the surface that is circumscribed by the anchors, then some of the anchors will not be bear the load correctly and the concrete part will tilt.

If the forces are not known exactly, the lifting anchors have to be selected to carry all the load on one anchor (see Safety Regulation UW 18 VBG 9a "Lifting Devices in Hoisting Operation").

**Table 4 – Examples for determining the number c of the load-bearing anchors in the precast concrete unit.**

**Attention! When determining resulting anchor force F, the adhesion in the formwork, acceleration etc. have to be taken into consideration.**

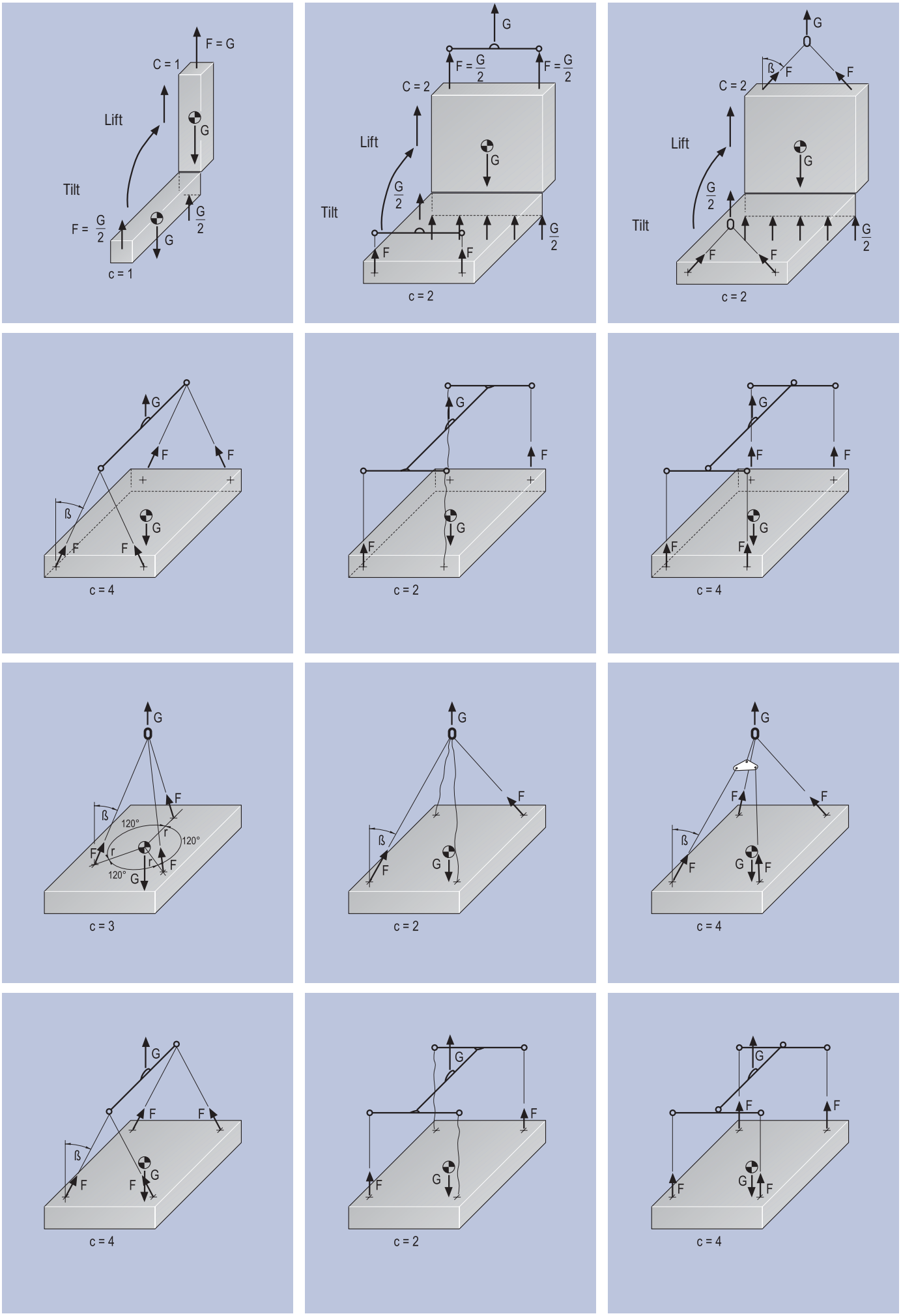
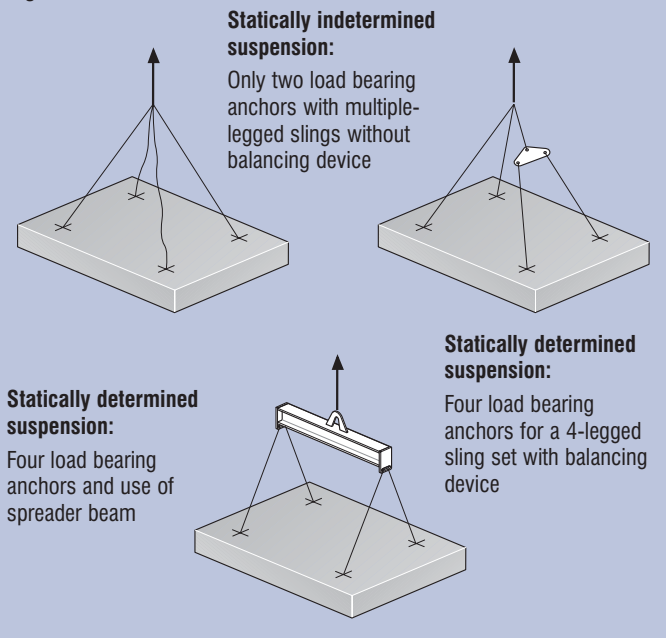


**Figure 7**




## 4.5 Statically indetermined suspension

A suspension can be called statically indetermined if it is not possible to distribute the load evenly to all anchors. This is generally the case with a beam with more than two anchor points and with a panel with more than three anchor points. Symmetrical arrangement cannot change this because the anchors can hardly be installed precisely set to fractions of millimetres and furthermore, the individual legs of a sling have certain length differences. At any rate, DIN standard 3088 allows up to 1% length difference between the individual legs of a sling.

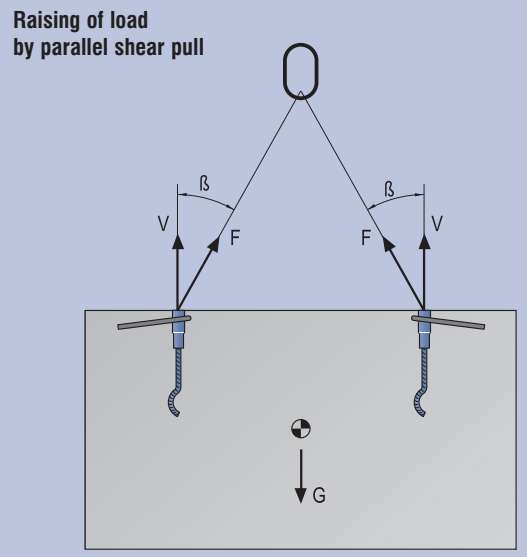
An even load distribution in the case of more anchor points can only be achieved if the unit to be lifted is sufficiently elastic, which rarely works without damage to the precast concrete unit, or with special balancing device (Figure 7).

When suspending on more than two suspension points without using balancing device, all anchors and the precast concrete unit have to be dimensioned according to the Safety Regulation in such a way that any two of the anchors can safely bear the entire load. For example, this is relevant for commercially available multiple-legged slings without balancing device and also for conventional H-shaped spreader beams without a balancing joint.

For this reason, the user should consider whether it would be economically advisable to acquire a balancing spreader beam or a balancing sling, since the anchors can mostly then be dimensioned smaller.

Table 4 shows some examples of determining the number of bearing anchors.

**Figure 8**




## 4.6 Parallel shear pull and transversal pull with multi-legged sling sets

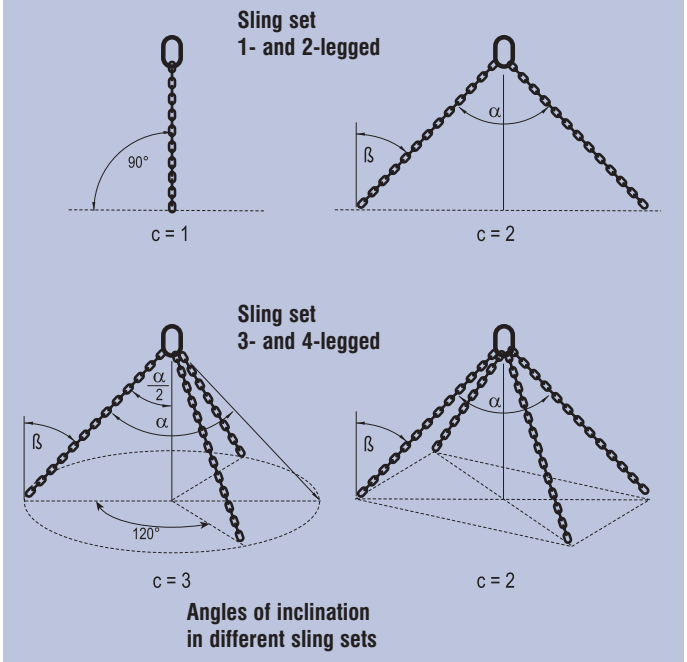
There are three fundamental types of stress for lifting anchors:

- **Straight pull:** stress in the direction of the axis of the lifting anchor
- **Parallel shear pull:** Load under angle of inclination ß to the vertical. In the case of lifting anchors installed on the facing side, the term parallel shear pull mostly refers to a strain in the direction of the precast concrete unit plane (Figure 8).
- **Transversal pull:** Traversal pull refers to the stress on a lifting anchor that is installed on the facing side in a panel-like precast concrete unit under an angle of inclination to the panel plane. In extreme cases, a panel subject to a transversal pull of 90° is tilted by the lifting anchors on the facing side (Figure 10).

These types of strain are looked at more closely in the special Installation Instructions in the respective Lifting Anchor Systems.

Due to inclined pull by the sling legs, the resultant force F on the anchor, lifting device and attachment device increases compared to the pure vertical force V depending on the angle of inclination β of the load (Figure 8). Vertical force V results from the dead weight, the arrangement of the anchors, number of load bearing anchors c, formwork adhesion, acceleration forces etc., as described above.

**Figure 9**




Resultant force F can be determined mathematically:

$$F = \frac{G}{c \cdot \cos \beta} \quad (5)$$

$$V = \frac{G}{c}$$

G = dead weight
V = component of vertical shear force
F = resultant force
c = number of load bearing anchors
cos β = factor for parallel shear pull

Figure 9 shows different types of sling sets with the angle of inclination α and the resultant angle of inclination β. Table 4 and table 5 can also be referred to. An angle of inclination β that is larger than 60° is not permissible because of the large increase in force according to the Safety Regulation.

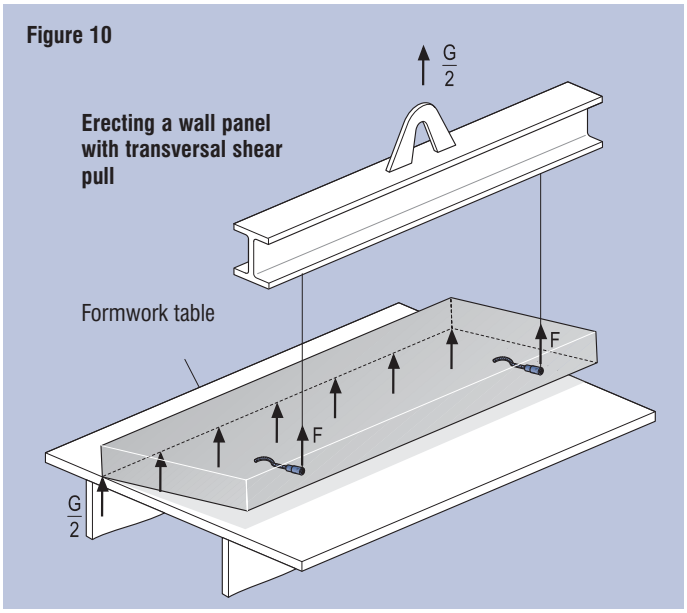
**Table 5 – Parallel shear pull factors**

| Angle of inclination α | 0° | 30° | 45° | 60° | 75° | 90° | 105° | 120° |
|---|---|---|---|---|---|---|---|---|
| Angle of inclination β | 0° | 15° | 22,5° | 30° | 37,5° | 45° | 52,5° | 60° |
| cos β | 1 | 0,97 | 0,92 | 0,87 | 0,79 | 0,71 | 0,61 | 0,5 |

## 4.7 Transversal shear pull during erection of horizontally lying panels

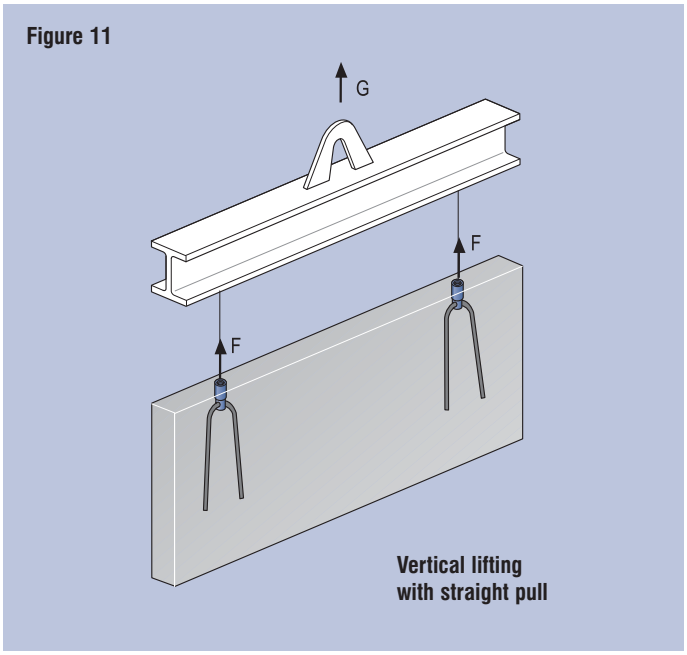
Transversal shear pull forces work when horizontally lying wall panels are erected. This means that the anchor is placed under stress at an angle of inclination of 90° with force F (see Figure 10). Since one side of the panel is still supported on the ground, only half of the panel weight has to be raised until the panel is in a vertical position. An additional transversal pull reinforcement must be installed in order that force F, which runs diagonally to the longitudinal axis of the anchor, can be absorbed. Precise information can be found in the Installation Instructions for the PFEIFER Thread System which is designed for loads under transversal shear pull.

**Figure 10**




After this, the entire weight has to be taken into consideration when vertical lifting takes place, as shown in Figure 11. Other load increasing factors, as described above, additionally have to be taken into account.

**Figure 11**




## 4.8 Determining the size of the Lifting Anchor

Resultant anchor force F, whilst observing the above influencing factors, is calculated as follows:

$$\text{res. } F = \frac{(G + Ha) \cdot f}{c \cdot \cos \beta} \quad (6)$$

res. F = resultant anchor force (kN)
G = dead weight of concrete unit (kN)
Ha = Formwork adhesion (kN)
cos β = factor for angle of inclination
c = quantity of load bearing lifting anchors
f = acceleration factor

After determining the decisive load case with corresponding resultant anchor force res. F, the user must then select the PFEIFER Lifting Anchor which has an admissible load capacity adm. F (in tons or kilograms) which is the same or greater than resultant force F which affects the anchor.

Proof: res. F ≦ res. adm. F (7)

During this selection, consideration must be given as to whether the entire system is suitable for the respective load cases. For example, BS Anchors that are installed on the facing side may not be suitable for lifting thin panels from a horizontal position. Attention should be paid that minimum panel thickness, edge distances etc. can be adhered to in accordance with the Installation Instructions and product data sheets.

## 4.9 Concrete compressive strength during lifting

All PFEIFER Lifting Anchors and the necessary additional reinforcements are designed for use in the concrete with a compressive strength at the first time of lifting of 15 N/mm$^2$. This corresponds to the strength of normal concrete which was east the previous day. Usage in cases with lower strengths is not covered by the values in the Installation Instructions. Additional conditions for use are given for the BS Anchor System with a concrete compressive strength of 30 N/mm$^2$.

PFEIFER Lifting Anchor Systems are designed for normal concrete providing that the specified technical conditions are observed. The technical data cannot be used without restrictions for light-weight concrete or gas concrete.

## 4.10 Installation with reduced panel thickness, edge-distances and intermediate distances

The “Safety Regulations for Lifting Anchors and Lifting Anchor Systems for Precast Concrete Units” ZH 1/17 from the employers’ liability insurance association has been in force in Germany since April 1992 after they were confirmed by the relevant EU committees.

For that reason, the installation tests that were necessary for PFEIFER Lifting Anchor Systems were carried out under **universally valid conditions** that were more rigorous. The tests were carried out at the Institute for Construction Materials in Baden-Württemberg, affiliated to the University of Stuttgart. Prof. Dr.-Ing. Eligehausen was in charge of the testing and an official expert.

All installation values in the catalogue such as edge distance, panel thickness etc. have been selected in such a way and have been confirmed by the tests, that they cover **the most unfavourable installation situations** imaginable and guarantee 2.5 times as much safety from concrete break-out. Therefore, safety is always ensured.

The basis for the **more rigorous testing conditions** were the following safety-oriented assumptions:

- **“Fresh concrete” with a lifting strength of 15 N/mm²**
- **The anchors were installed in panels with a minimum panel thickness on the head side.**
- **The panels were only reinforced with mesh on the lower and upper side of the panel.**
- **There were no rebar stirrups in the edges of the panels.**
- **There were no seam rebars or distributor applied.**
- **The distances between the anchors were established according to the rules valid in the fixing technology for non-reinforced concrete with between 3 and 4 times the depth of anchoring, edge distances are half as much.**
- **The panel thicknesses are specified exclusively for the decisive “Lifting with transversal shear pull” load case (in order to avoid confusion with the more favourable panel thickness for the “straight pull” load case).**

**PFEIFER Installation Instructions do always cover these admittedly unfavourable conditions in order to constantly be on the safe side. In most cases, there are however, considerably more favourable conditions available which makes it possible to deviate from the required Installation Instructions without affecting the necessary safety.**

These are in detail:

- **higher concrete compressive strength**
- **panel edges with rebar stirrups**
- **additional reinforcement in the area of the Lifting Anchor**
- **load capacity that is not fully used**
- **anchors with larger bond length (special lengths or over-dimensioning)**
- **only straight pull or parallel shear pull without transversal shear pull components**

The edge and intermediate distances are not critical with normally reinforced units with rebar framed edges.

If additional reinforcement is installed it is possible to deviate fundamentally from the Installation Instructions. However, it is not possible to increase the load capacity in this way.