

**Macsim Technical Division**

# **STRUCTURAL ANCHORING SYSTEMS**

***THE COMPREHENSIVE TECHNICAL  
SUPPORT MANUAL FOR***

**MACSIM  
ANCHOR SYSTEMS**

**MAY 2005**

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# STRUCTURAL ANCHORING SYSTEMS

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# **The Complete MACSIM Package**



Macsim Fasteners have evolved into a National Provider of Quality fastening and allied hardware Systems.

We have been established for over 50 years with a wealth of experience in Fixing solutions as a result.

This manual is designed to give both the 'casual' user and the Technical Specifier the information they require in the most plain format possible.

The 'Simple' load tables give fast, easy to follow steps to enable the user to apply the right product to their fixing solution.

The Limit state design methods are based on the European EOTA guidelines using our own test data developed from extensive independent testing in Australia. The steps are logical and give a reliable safe load capacity for the actual application under Consideration.

Whether you require basic load data for a simple fixing such as the Macsim Macplug, or full limit state design data for the Macsim Chemcap anchor; you will find it all within this manual.

**If you have any queries, please contact our Technical Dept.**

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### FIXING EFFICIENCY

*The “efficiency” of a fixing can be determined by the way in which it fails and this is therefore the basis on which anchor or fixing selection should be made:-*

- ◆ Where the anchor actually breaks, it would be possible to use a stronger fixing or a larger size to reach higher loading capacity
- ◆ If the Base Material breaks in the form of a ‘cone’ around the anchor, the anchor could be set deeper to extract more performance or a smaller one could be used to achieve the same result
- ◆ If the anchor simply pulls out, the size of the anchor is too small or it is the wrong type for the base material to achieve full efficiency
- ◆ If the Base material completely fails; i.e. The Concrete slab cracks; the anchor is over specified and a smaller or less powerful one could be used to achieve the same fixing performance

### WHAT IS FAILURE?

*The Failure of a fixing is somewhat dependant on interpretation or on the required safety of the system;*

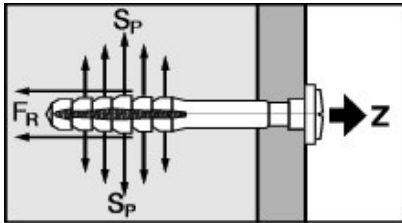
1. If an anchor ‘slips’ more than a pre-specified amount, it may be deemed to have failed as the component is no longer fixed tightly and it is therefore no longer operating
2. Failure is only when total collapse of the fixing occurs; as per the modes above

The Specifier must determine what criteria he requires and this would normally depend on the design of the attachment, the critical nature of it and the implications of failure.



**TYPES OF FIXINGS**

*Different types of anchors act in different ways to achieve their loading power and in the way that they typically fail.*

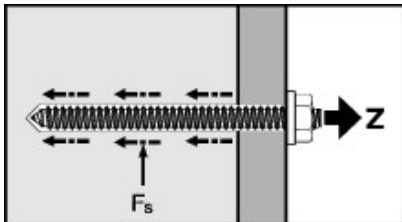


*Fig (3.1) Illustration shows the Macsim Bettadrive anchor, a drive in screw and nylon plug type which can also be easily removed*

**FRICITION TYPE ANCHORS**

*These include all Plastic wall plugs, nylon bodied anchors, nails and light duty metal sleeved anchors.*

The expansion of the plug creates a friction force ( $F_R$ ) between it and the base material inside the hole. Provided the pull out force ( $Z$ ) does not exceed  $F_R$ , no real movement (slip) occurs. Once exceeded the anchor will pull out under decreasing load capacity.



*Fig (3.2) Illustration shows the Macsim Chemcap or Quickfix type chemical anchors. No movement can occur until pull out force  $Z >$  the adhesive/keying force  $F_s$*

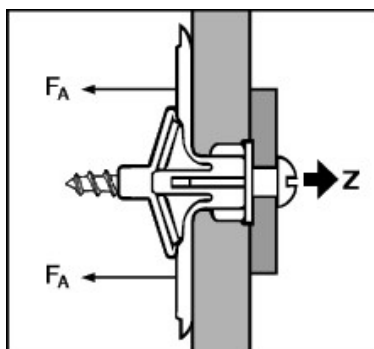
**ADHESIVE TYPE ANCHORS**

*These include all Chemical anchors, glues and grouts that interface between the base material and some type of anchorage such as a threaded stud or ribbed bar.*

Chemical Anchors, such as Macsim Chemcap system and Macsim 'Quickfix' system, resist load by creating a keying resistance between the hole surface and the anchor stud or insert. This is formed by the adhesion of chemical mortar to both rough surfaces.

This adhesion force, or 'bond strength' is a function of the type of base material, the type of stud/insert used and temperature.

Generally, these anchors have little or no slip at low temperature. Macsim chemical anchors will give excellent slip performance at temperatures below 25<sup>0</sup> C in concrete.



*Fig (3.3) Illustration shows a Macsim Butterfly Toggle. This fastener tightens back on the reverse side of plaster or other board to create a keying resistance*

**KEYING TYPE ANCHORS**

*These include all through wall fixings, hollow wall anchors and toggles.*

The Bearing force  $F_A$  must be exceeded by the pull out force  $Z$  for this type of anchor to fail. This type could be as simple as a bolt through a wall with a bearing plate placed behind to create the bearing force, or a toggle such as that shown.

With this type, movement is only due to stretching of the anchor or actual base material.

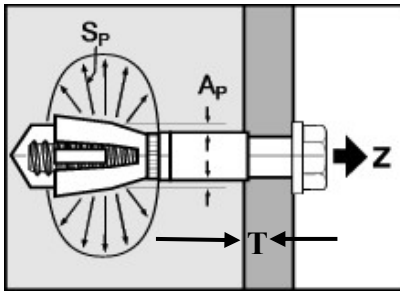


Fig (3.4)  
Illustration shows a Macsim HLS Anchor. This type of expansion anchor offers torque - controlled pre-tension  $T$  that must be exceeded by the load before any slip occurs.

**TORQUE CONTROLLED EXPANSION TYPE ANCHORS**

*This type are strong enough to cause local concrete crushing around an expansion zone which is created by tightening up a bolt/stud causing a tension force to be induced.*

With this type, by expanding and keying into the base material a tension force is created in the anchor bolt as it is tightened up and stretched between the expansion cone and the fixture surface.

This tension force is directly related to the torque applied in tightening and setting the anchor, making the amount of torque critical.

The anchor will only start to slip when the tension force  $T$  is less than the Pull out force  $Z$ .

It should also be noted that “torque relaxation will occur, Causing a reduction in the tension force  $T$  in time; see Section 4; Long Term Performance of Anchors.

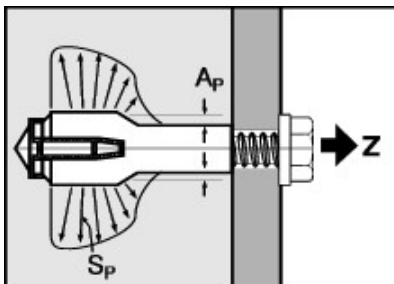


Fig (3.5)  
Illustration shows a Macsim Mason anchor. This type of expansion anchor offers no pre-tension but can be set flush with the concrete surface.

**FORCED EXPANSION TYPE ANCHORS**

*This type are of a strong enough metal construction to cause local crushing of the base material (normally Concrete of strength greater than 25MPa) and where the expansion is formed by using an independent force.*

Anchors such as the Macsim Mason anchor; drop-in type, function in this way: A punch is used to force a plug a specific distance inside the ‘shell’ to cause the correct amount of expansion.

These Anchors have little or no pre-tension and will therefore fail quickly after little movement.

The advantage is that they require fairly shallow drill depths to function. They should only be used in hard base material such as Concrete  $> 25$  MPa.

## **KEY INFLUENCES**

*There are several key factors which influence a fixing performance beyond the anchor type and type of loading;*

- ◆ Base Material Type and Quality
- ◆ Base Material Dimensions, particularly Depth of Substrate and likely Edge Distance
- ◆ The Depth the Anchor is embedded in the Base Material
- ◆ The distance between Anchor and Edge (Edge distance) and other anchors (Spacing)
- ◆ Long Term Performance requirements
- ◆ Resistance to Fire or Heat/Cold effects
- ◆ Corrosion

### **4A Base Material**

"A Fixing is only as good as the material you are fixing to."

This is the golden rule of fixing and fastening and although obvious, is often overlooked.

All Macsim test results have been established in Concrete that is sound, of minimum 25Mpa (N/mm<sup>2</sup>) strength and has reached this strength within normal curing time; 28 days.

We cannot predict anchor performance in any material outside of these parameters.

Particular care should be taken when fixing into concrete or Masonry of unknown quality.

### **4B Base Material Dimensions**

Apart from the distance that the anchor is placed in relation to the edge of a structure or another anchor, the thickness of the base material is also critical.

This is particularly so with expansion anchors, as they create a stress zone which goes behind the anchor. ( See section 3)

When using an impact type hammer drill, the hole depth must not go within 30mm of the base of a concrete structure. E.G. The structural thickness must be 30mm or more greater than the required hole depth.

If dimensions are tight, we recommend the use of the Macsim Chemcap Chemical anchor system. This does not apply any stress to the base material until the anchor is loaded.

### **Concrete Reinforcement**

Reinforced concrete offers some improvement in anchor performance as it strengthens the base material. However, as there is not usually any way the designer of an anchor system can predict where the reinforcement will be, it is not taken into consideration. Moreover, anchor tests are carried on in un-reinforced concrete.

## 4C Depth of Embedment

The greater the depth of embedment, the more base material is being gripped by the anchor.

At a certain point, dependant on the anchor strength, increasing the depth no longer has any beneficial effect, and the anchor itself will break. Macsim specify the 'optimum depth of embedment' for each type and size, of anchor and the loads that can be expected at this depth. When using Ultimate Limit State Design, Macsim have shown the effect of various embedment depths on the high performance anchor systems.

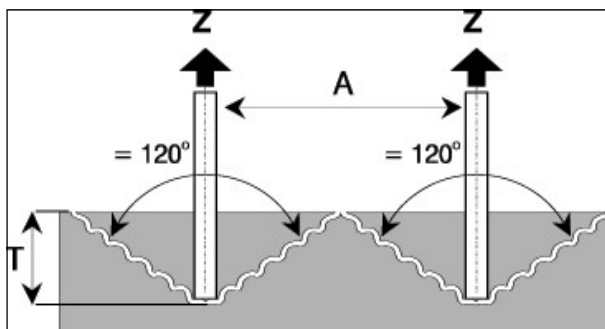


Figure:- Anchor Spacing

A = spacing of anchor  
 Z = Tensile load  
 T = Depth Of Embedment

## 4D Anchor Spacing and Edge Distance

### Anchor Spacing

The distance between anchors determines the effect they have on each other. In basic terms, each anchor has a "field of influence" which is described by a 'cone' of base material; see figure left; This 'cone' will increase in size in relation to the depth of embedment.

Provided the 'cone' of an anchor is not effected by one of a neighbour, the full performance can be expected.

As the 'neighbour's cone' clashes with the anchor considered, the amount of load it can withstand will be reduced accordingly.

At some pre-determined point, the value of placing two anchors together becomes less than having just one single one.

### Edge Distance

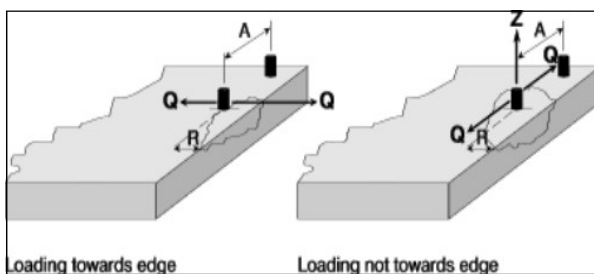


Figure:- Edge Distance

A = spacing of anchor  
 Z = Tensile load  
 Q = Shear Load direction  
 R = Edge Distance

In a similar way to spacing; if the 'cone' of the anchor is reduced by the proximity of the base material's edge; the performance will be reduced.

For loading in shear; e.g. across the axis of the Anchor, in direction 'Q' in the Figure left, the effect of an edge will depend on the direction of the load.

If the load is towards the edge; the effect will be much greater than when it is parallel or at right angles to it (tension).

Macsim have given shear loading reduction factors for our products assuming load towards the edge.

**4E Long Term Performance**

When an Anchor or Fastener is specified for an application, it is important to consider it's long term performance.

If the 'connection' is only required for a short time; say in temporary works applications, it may be possible to reduce the safety factors applied to the ultimate performance.

Most Fastenings are designed to last an indefinite period and so their performance over time becomes a major factor.

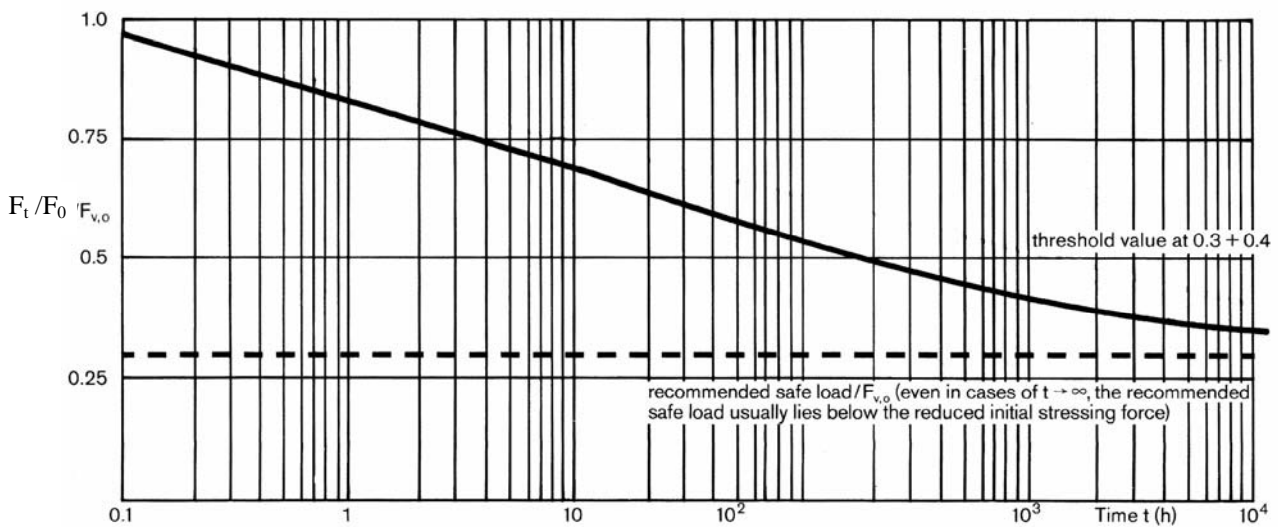
Maccsim give recommended loads that generally take this requirement into account. Ultimate Limit State Design may also require additional factors to be applied if long term performance is critical.

There are several key factors that effect Anchor types in their long term performance;

**4E.1 Torque Relaxation in Expansion Anchors**

The natural relaxation of any material subject to tension must be considered. The diagram below is taken from testing carried in Germany in the early Eighties on Anchors similar to the Maccsim HLS High Load Safety Anchor.

Any anchor that performs by expansion achieved by torque will act in this manor; Both bolt and Concrete will relax with time.



$F_t$  = Pretension force at time = t  
 $F_0$  = Pretension force at time = 0 =  $F_{v,0}$

The Dotted line is the level at which the real safe working load of this type of anchor should lie, if long term slip resistance is required. Maccsim have been careful to recommend a working load below this for the High Performance anchors; HLS and Wedge.

# INFLUENCES ON FIXING PERFORMANCE 4

## 4E Long Term Performance

### 4E.2. Creep in Chemical and Adhesive Fixings

Chemical anchors of most types perform well under long term constant load and even live load.

However, the temperature of the resin mortar will influence the amount of long-term slip the anchor will demonstrate;

The following Table compares the performance of Macsim Chemcap anchors under **full recommended working load** over time, dependant on temperature;

Mortar Temp °C	Initial Slip	After 10 Days	After 100 Days	After 1 year	After 10 years
20	0.09mm	0.15mm	0.25mm	0.26mm	0.28mm
40	0.30mm	0.51mm	0.52mm	0.53mm	0.55mm
50	1.00mm	1.50mm	1.60mm	1.70mm	1.80mm

*These temperatures represent the average mortar temp, not ambient.*

### 4E.2. Expansion loss in Light Duty plugs

Long term performance of Nylon bodied fixing systems are effected by the constant decrease in expansion pressure exerpted on the drill hole by the plug. It has been shown that frictional coefficient of resistance of the nylon material does however, improve with the reduction in expansion pressure, compensating some of the loss.

Generally, Macsim quality nylon fixings, such as Frame, Bettadrive and Nail-N-Plug, will lose some 30% of their frictional resistance to pull out over 10 years. Beyond this, the loss appears extremely small.

It is important that the Macsim Nylon Fixings are not used in temperatures in excess of 60<sup>0</sup> Centigrade, as beyond that they may enter the 'thermo-elastic' stage where they will mould themselves into the shape of the expansion and offer no further resistance.

It should be noted that plastic plugs such as Macsim 'Wall-plug' cannot be considered as long term fixings due to the nature of their material.

Macsim Nylon Fixings are resistant to UV light and will function correctly in a temperature between - 30<sup>0</sup>C and + 60<sup>0</sup>C.

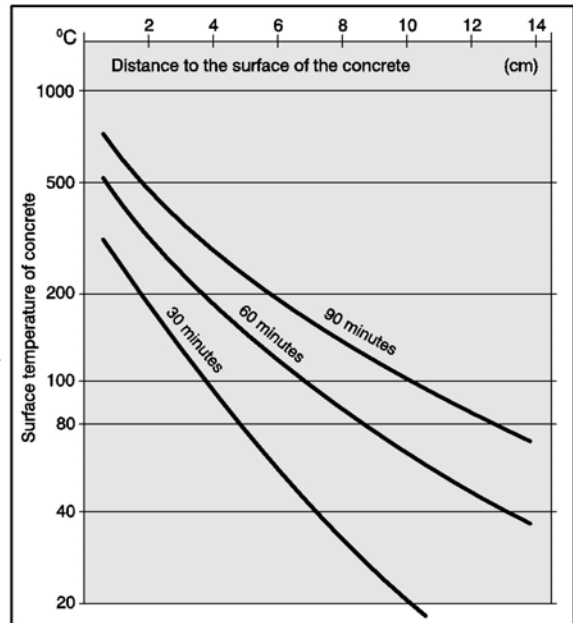
**4F Fixing Performance in Fire**

**4F.1. Mechanical Expansion Anchors;**

This figure shows the temperature developed inside a typical concrete component during a full scale fire test.

The Specifier of an anchor system should note that any all-metal type anchor, such as Macsim HLS, Wedge, Masonbolt and Mason anchor must not be subjected to temperatures in excess of 250°C. Above this, the yield strength of the material will be destroyed.

Anchors should be embedded deep enough to dissipate the heat and protected to avoid surface bolt breakage.



*Figure; Heat Transfer in concrete in time; surface temp = 1000°C*

**4F.2. Chemical—Adhesive Anchors**

Once a temperature of 60°C is reached, the chemical mortar will lose strength rapidly and will no longer adhere to the surfaces.

However, the ability of the resin to dissipate heat rapidly to the base material it is in contact with, enables it to resist for some time, the attack of a surface fire; especially if the resin is maintained in the hole. (Not recommended for applications where the anchor will be holding a suspended load from a soffit)

Only 1/3<sup>rd</sup> of the embedment depth in the case of the Macsim Chemical Anchor needs to be working to provide maximum working load and thus for a temporary fixing during a fire, 2/3<sup>rd</sup> can be sacrificed.

Using the figure above, and embedding the resin anchor at a suitable depth, a time related fire rating can be achieved.

**4F.3. Nylon and other Light duty plastic fixings**

Macsim cannot provide any information about the resistance of nylon or plastics in fire. We do not recommend their use for critical fixings in a fire threatened environment.

**4G Corrosion Resistance**

**4G.1. Zinc Plated and Passivated**

Electro—Zinc Plating with clear or Yellow passivation is primarily designed to give a clean, long lasting finish in non corrosive environments.

Macsim recommend this finish for internal, dry conditions or where only a very short period of usage is required.

**4G.2. Mechanically Galvanized**

For external application, where the fastener is likely to be subjected to normal rain and weather effects, but is away from salt or air pollution, the Macsim range of Galvanised Fasteners would be ideal.

**4G.3. Stainless Steel**

Where the application is within 5 Kms of the coast, is of a critical nature and long term performance is required, Macsim recommend the range of Stainless Steel Anchors. All Macsim Stainless Anchors are of the high grade, 316 (AISI A4) grade Stainless unless otherwise indicated.

The Chart Below indicates which materials the Macsim Range of Fixings are available in:-

<b>Macsim Product</b>	<b>Zinc Plate</b>	<b>Galvanised</b>	<b>Stainless Steel</b>
MACSIM HLS	Yes	(Special**)	
MACSIM WEDGE	Yes	Yes	Yes
MACSIM MASONBOLT	Yes	Yes	Yes
MACSIM MASON ANCHOR	Yes	(Special**)	Yes
MACSIM CHEMCAP STUDS	Yes	Yes	Yes
MACSIM SCREWBOLT	Yes	Yes	(Special**)
MACSIM MACLOC	Yes		
MACSIM METAL FRAME	Yes		
MACSIM FRAME ANCHOR	Yes	Yes	(Special**)
MACSIM BETTADRIVE	Yes		Yes
MACSIM NAIL-IN PLUGS	Yes		Yes

*\*\* Macsim can produce these to special order, dependant on quantity and lead time required.*

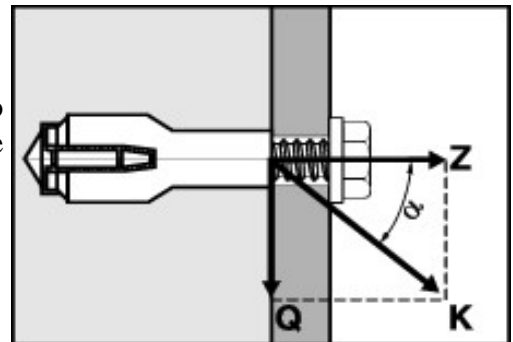
**LOADING INFLUENCE**

*The type and direction of loading has a critical effect on the performance of a fixing system.*

- ◆ Load in one direction only; e.g. tensile loading; or by shear and tension in combination?
- ◆ Fixing likely to incur bending—off set loading?
- ◆ Load is static; e.g. weight only? (“Dead Load”)
- ◆ Load is static plus changing load (“Live Load”)
- ◆ Loading may be coupled with vibration?

**5A Direction of Load**

The direction and the point at which load is applied to an anchor has an enormous effect on the resistance that the anchor can provide.



The ‘Normal’ direction of load is pure tension ‘Z’, or directly along the axis of the anchor. Any deviation is measured as an angle from this direction.

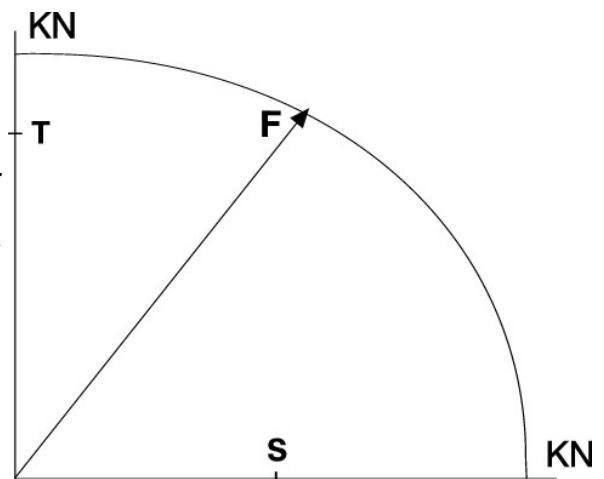
The capability of the anchor shown in the product details assume perfect tension or shear directional loading before applying reduction factors for any variation.

To simply calculate the suitability of an anchor to resist a loading, the following formula can be considered;

$$\frac{\text{Actual T.}}{\text{Rec. T}} + \frac{\text{Actual S.}}{\text{Rec. S}} < 1 \quad (\text{Where T is tension load and S is Shear load; Rec. T is advised safe tension, Rec. S is safe shear})$$

*This requirement can be ignored provided the resultant loading is within 10° of either pure tension or shear.*

For critical applications, contact Macsim’s technical department for guidance.  
[technical@macsim.com.au](mailto:technical@macsim.com.au)

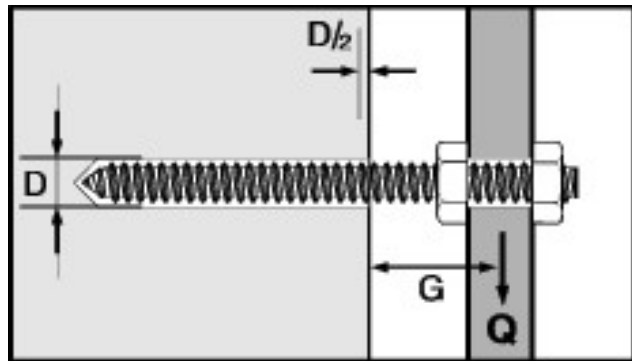


**5B Bending Stress**

The bending moment can be calculated using the following formula. Note figure:-

$$M = Q (g + D/2)$$

Where M is bending moment  
Q is actual lateral load.



The size of an anchor required can be determined by the equation  $M_A = M/X$

X = The axial moment of resistance, which for a round section is  $(d)^3/10$ , and for a Hollow Round section (e.g. anchor Sleeve) is  $(D^4-d^4)/10.D$ . (D= outside dia)

The allowable bending stress can be determined from the material specification.

The loads given in the technical data for Macsim Fixing Systems assume Loads act along the axis or directly from it.

If the surface of the base material, the line on which the load acts and the centre line of the anchor, do not have a common point or intersection, the anchor enters into a bending stress. This will drastically reduce the ability of the anchor to resist load.

Loads applied to an anchor at any distance from the base material surface create an additional lever arm, 'D/2' in fig. above. This is due to the crushing effect the anchor has on the base material as it deflects.

The amount we consider is normally 1/2 of the hole diameter

Provided the fixed component is clamped to the base material, it cannot rotate and no real bending can occur.

**5C. Type of Loading**

The Specifier should also consider the **type of loading** when calculating safety factors applied to fixing performance.

Macsim have assumed predominantly static, dead loads in producing the tables given in this manual.

If Live loading such as constant vibration, or sudden load changes (shock loading) are likely, then further safety factors must be applied in accordance with the relevant Australian Standard recommendations. This is normally applied by increasing the size of the loading requirement on the fixing system.

Macsim have no data available on the ability of anchors to resist torsional loading.

*The type of Anchor required to be most efficient and effective is not a black and white decision.*

*The chart attempts to at least point the specifier in the right direction.*

*Care should then be taken to assess the chosen product by matching its performance with that required in the application being considered.*

*The following key steps to take are recommended in considering a solution to a fixing application.*

*Please contact the Macsim Technical Services Department if you are in any doubt about the correct choice of fixing.*

## **FIXING PRODUCT SELECTION PROCEDURE**

### **1. ASSESS WHAT THE BASE MATERIAL TYPE IS THAT YOU ARE FIXING TO**

IF STRENGTH DATA IS AVAILABLE OR TESTING CAN BE UNDERTAKEN, THIS WILL ALLOW FAIRLY ACCURATE MEASURE OF PERFORMANCE.

### **2. CONSIDER WHAT THE LOAD CONDITIONS ARE LIKELY TO BE;**

LONG TERM APPLICATION  
STATIC AND LIVE LOADING  
CRITICAL NATURE OF FAILURE

### **3. CONSIDER THE ENVIRONMENTAL CONDITIONS**

IS IT AN INDOOR APPLICATION? HOW NEAR TO SALT CARRYING ATMOSPHERE?

THIS WILL DETERMINE WHICH MATERIAL AN ANCHOR SHOULD BE SPECIFIED IN; ZINC PLATED, GALVANISED OR STAINLESS STEEL









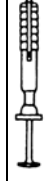

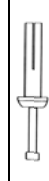









### **4. CONSIDER THE AESTHETIC APPEARANCE OF THE FIXING**

A WIDE RANGE OF THE MACSIM FIXING PROGRAM CAN BE SUPPLIED WITH DIFFERENT 'HEAD STYLES'; E.G. MACSIM MASONBOLT CAN BE SUPPLIED WITH HWF NUT, FLUSH HEAD BOLT, COUNTERSUNK HEAD BOLT OR PAN HEAD BOLT.

# FIXING SELECTION 6

## BASE MATERIAL AND LOADING REQUIREMENT

### MACSIM FIXING

		Concrete Heavy Duty	Concrete Med. Duty	Concrete Light Duty	Solid Brick Med. Duty	Solid Brick Light Duty	Hollow Brick Med. Duty	Hollow Brick Light Duty	Natural Stone, Solid Heavy Duty	Natural Stone, Solid Light Duty	Natural Stone, Fissured	Lightweight Solid Block	Lightweight Hollow Block	Plasterboard Cavity Wall	Wall Board with Cavity
8	HLS HEAVY DUTY EXPANSION		M												
9	WEDGE ANCHOR THROUGH BOLT		M	M											
10	MASONBOLT SLEEVE ANCHOR		M	M	M										
11	MASON ANCHOR DROP IN		M												
12	CHEMCAP CAPSULE AND STUD		M		M										
13	QUICFIX INJECTION MORTAR		M	M	M	M					M	M	M		
14	SCREWBOLT		M	M	M	M				M					
15	FRAME ANCHOR NYLON				M	M				M			M		
16	BETTADRIVE SCREW - PLUG				M	M				M					
17	MFA METAL FRAME ANCHOR				M	M				M					
18	MACDRIVE METAL NAIL-IN				M	M				M					
19	MACLOC SHIELD ANCHOR				M	M				M					
20	MACPLUG NYLON PLUG				M	M				M		M			
21	SPLITZ HAMMER IN ANCHOR				M	M									
22	NAIL IN PLUG				M	M									
23	HOLLOW WALL ANCHOR													M	M
24	METAL TOGGLE ANCHORS													M	M
25	PLASTIC TOGGLE ANCHORS													M	M
26	WALL LOK HOLLOW WALL PLUG													M	M
27	PLASTIC WALL AND SUPER PLUG					M								M	M

‘M’ Notates a Fixing recommended by Macsim for this range of application  
 ‘M’ Notates a Fixing that can be applied in certain conditions, but is not recommended

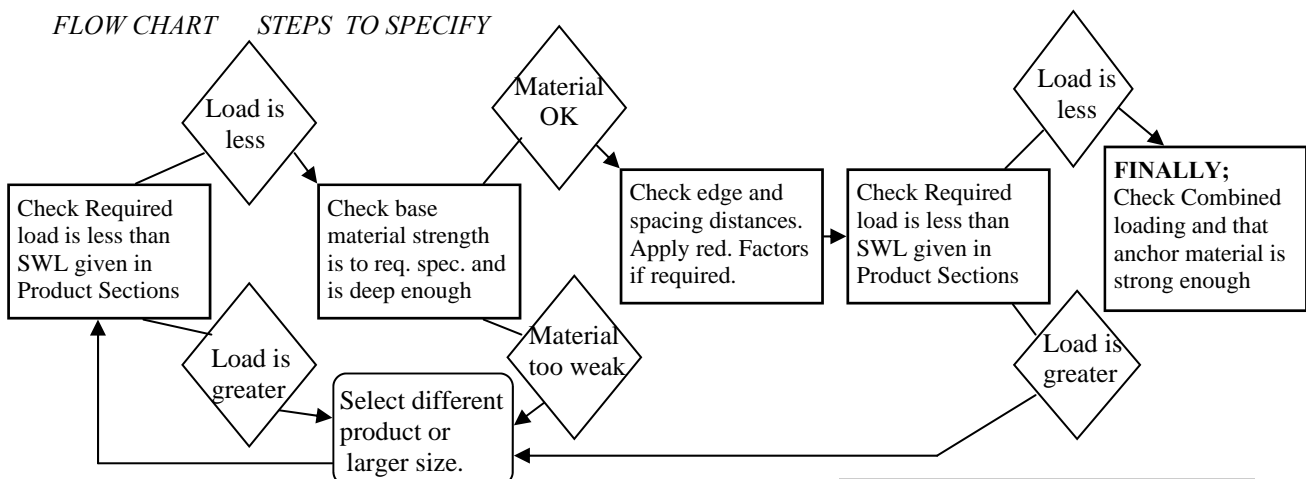
*Macsim's Fastening Systems can be assessed for suitability utilising two methods of design; The, traditional, safe working load factors method or the more precise and efficient ultimate limit state design method. The following sets out the alternative procedures and guides how to use the data provided with each product.*

## 7A SAFE WORKING LOAD METHOD

- 1) CHECK REQUIRED LOAD PER ANCHOR IS LESS THAN THE “ADVISORY SAFE LOAD” GIVEN IN THE DESIRED FASTENING SYSTEM’S TECHNICAL SUMMARY FOR BOTH TENSILE AND SHEAR.
- 2) CHECK THAT THE BASE MATERIAL IS NOT AFFECTING PERFORMANCE DUE TO STRENGTH BY REVIEWING THE CONCRETE STRENGTH REDUCTION FACTORS TABLE, IF SO, APPLY FACTOR.
- 3) CHECK THAT THE ANCHOR IS NOT EFFECTED BY AN EDGE BY REVIEWING THE CLOSE EDGE REDUCTION FACTOR TABLE FOR TENSILE OR SHEAR. IF SO, APPLY THE SUGGESTED FACTOR.
- 4) CHECK THAT THE ANCHOR IS NOT EFFECTED BY A NEIGHBOUR BY REVIEWING THE ANCHOR SPACING REDUCTION FACTOR TABLE FOR TENSILE AND SHEAR. IF SO, APPLY FACTOR.
- 5) CHECK THAT THE TENSILE AND SHEAR LOAD IS NOT COMBINING TO REDUCE THE ANCHOR’S CAPACITY BY REVIEWING THE EQUATION;
 
$$\frac{\text{Actual Tension}}{\text{Rec. Tension}} + \frac{\text{Actual Shear}}{\text{Rec. Shear}} < 1$$
- 6) CHECK THAT THE ANCHOR STEEL STRENGTH IS GREATER THAN THE LOADS CALCULATED ABOVE. IF NOT, USE THE ANCHOR STEEL STRENGTH (SAFE WORKING).

NOW REVIEW THAT THE FINAL ADVISORY SAFE LOAD IS SUFFICIENT TO MEET YOUR REQUIREMENT PER ANCHOR. IF DEFICIENT, CHOOSE A LARGER OR STRONGER FASTENING SYSTEM FROM THE MACSIM RANGE.

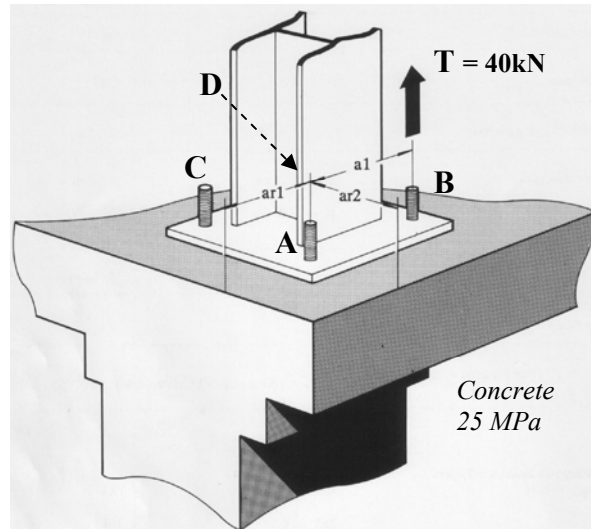
FLOW CHART STEPS TO SPECIFY



## 7A SAFE WORKING LOAD METHOD

## WORKED EXAMPLE; SAFE WORKING LOAD METHOD

- 1) CHECK LOAD PER ANCHOR AGAINST SIMPLE LOAD TABLES AND CHOOSE PRODUCT;
- 2) TRY MACSIM CHEMCAP M16 HAS 16.7 Kn; SWL IN TENSION ( $4 \times 16.7 = 66.8\text{Kn}$ )
- 3) EDGE DISTANCE  
 $ar1 = 110\text{mm}$   
 $ar2 = 100\text{mm}$   
 SPACING (SQUARE COL)  $a1 = 240\text{mm}$
- 4) CONCRETE DEPTH = 160mm
- 5) CHECK CONCRETE STRENGTH AND SIZE; SIZE OK, (DEPTH) 25MPa;  $f_{cst} = 1.0$



- 6) CALCULATE EDGE DISTANCE FACTORS; CONSIDER ANCHOR A.

FROM TABLE IN CHEMCAP SECTION 12; FOR  $ar1$   $f_{adt} = 0.91$   
 FOR  $ar2$   $f_{adt} = 0.85$

(ANCHOR B; FOR  $ar1$  (350mm)  $f_{adt} = 1.0$ ; FOR  $ar2$   $f_{adt} = 0.85$ )  
 (ANCHOR C; FOR  $ar2$  (340mm)  $f_{adt} = 1.0$ ; FOR  $ar1$   $f_{adt} = 0.91$ )  
 (ANCHOR D; FOR  $ar1$  (350mm)  $f_{adt} = 1.0$ ; FOR  $ar2$  (340mm)  $f_{adt} = 1.0$ )

- 7) CALCULATE SPACING FACTORS; ALL ANCHORS APPLY; BUT A CONSIDERED;

FROM TABLE IN CHEMCAP SECTION 12; FOR  $a1$  ( $A > B$ )  $f_{ast} = 0.98$   
 FOR  $a2$  ( $A > C$ )  $f_{ast} = 0.98$   
 FOR  $a3$  ( $A > D$ )  $f_{ast} = 1.0$

- 8) CHECK SHEAR AND TENSION COMBINED LOADING;

IN THIS CASE NO SHEAR LOADING IS PRESENT

NOW CALCULATE LOAD; CONSIDER ANCHOR A AS THE WEAKEST IN GROUP;

$$SWL \text{ LOAD} = 16.7\text{KN} \times f_{adt} \times f_{ast} = 16.7 \times 0.91 \times 0.85 \times 0.98 \times 0.98$$

SWL LOAD ALLOWABLE ON ANCHOR A = 12.41Kn. THEREFORE B - D OK.

M16 CHEMCAP CAPABLE OF MEETING REQUIRED LOADING IN THIS CASE.

## 7B ULTIMATE LIMIT STATE DESIGN METHOD

*This method differentiates between the possible failure modes; e.g. Pull out, anchor failure (steel), base material failure; and allows for different safety factors to be applied dependant on the mode of failure.*

*This can mean higher allowable safe working loads (efficiency) whilst ensuring that safety factors for any contingency have been applied.*

*Moreover, this approach is in keeping with modern design methods and in the AS building codes.*

*Macsim have simplified the European Design Guide for fasteners (ETAG 001 Parts 1 - 6, Annex A - C) to enable the Specifier to quickly assess the fastener's capabilities and applicability.*

*There are 3 load considerations to be made; Tensile, Shear and Combined. For Tensile there are three potential modes of failure; pulling out of the anchor, base material - concrete failure and anchor-steel failure. For Shear there are two; concrete failure and anchor failure. For combined tensile and shear loading the angle loading formula must be satisfied.*

### 7B 1) TENSILE CAPACITY ASSESSMENT

ANCHOR PULL-OUT	CONCRETE FAILURE	ANCHOR FAILURE (STEEL)
<p><i>Establish;</i>  <b>-<math>T_{cfp}</math></b> Characteristic Design Capacity</p> <p><b>-<math>f_{cst}</math></b> Concrete strength factor</p> <p><b>-<math>f_{aet}</math></b> Anchor embed. depth factor</p> <p>Now Anchor pull out Capacity;  <math>T_{apc} = T_{cfp} \times f_{cst} \times f_{aet}</math></p>	<p><i>Establish;</i>  <b>-<math>T_{cfc}</math></b> Characteristic Design Capacity</p> <p><b>-<math>f_{cst}</math></b> Concrete strength factor</p> <p><b>-<math>f_{aet}</math></b> Anchor embed. depth factor</p> <p><b>-<math>f_{ast}</math></b> Anchor spacing factor</p> <p><b>-<math>f_{adt}</math></b> Anchor edge distance factor</p> <p>Now Anchor Concrete Capacity;  <math>T_{acc} = T_{cfc} \times f_{cst} \times f_{aet} \times f_{ast} \times f_{adt}</math></p> <p>Take lowest from <math>T_{apc}, T_{acc}, T_{cfs}</math>  <math>= T_{ulsd}</math></p> <p>Check;            Required Tensile capacity &lt; <math>T_{ulsd}</math></p>	<p><b><math>T_{cfs}</math></b> Design Capacity steel</p>

## 7B ULTIMATE LIMIT STATE DESIGN METHOD

## 7B 2) SHEAR CAPACITY ASSESSMENT

*The shear capacity of the anchor is assessed between the strength of the steel material and the resistance capacity of the base material—concrete.*

*The load direction; towards or away from an edge has a significant effect on the capacity*

**CONCRETE (EDGE) FAILURE**

*Establish;*

- $S_{cfc}$  Characteristic Design Capacity

- $f_{css}$  Concrete strength factor

- $f_{asds}$  Anchor spacing & edge factor

- $f_{dts}$  loading direction factor

Now Anchor Concrete Shear Capacity;

$$S_{acc} = S_{cfc} \times f_{css} \times f_{asds} \times f_{dts}$$

Take lowest from  $S_{acc}$ ,  $S_{cfs}$   
 $= S_{ulsd}$

Check;

Required Shear capacity <  $S_{ulsd}$

**ANCHOR FAILURE (STEEL)**

$S_{cfs}$  Design Capacity steel

## 7B ULTIMATE LIMIT STATE DESIGN METHOD

### 7B 3) COMBINED LOADING (Limit State Design)

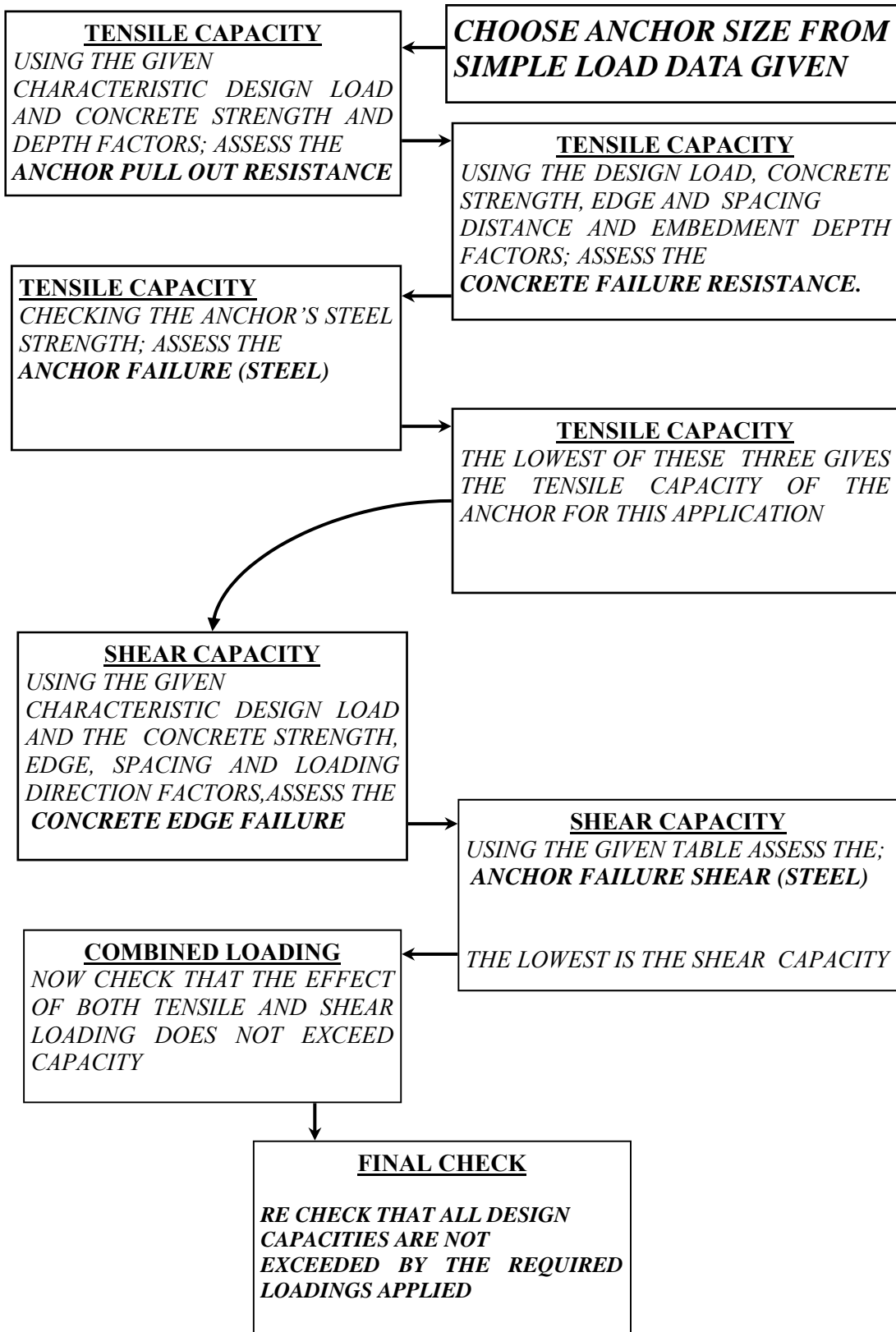
*To ensure the Fastening system's suitability in the case of combined shear and tensile loading for the application the following formula must be satisfied;*

$$\frac{T}{T_{\text{ulsd}}} + \frac{S}{S_{\text{ulsd}}} < 1.2$$

*Where*

- T** = Required Applied Tensile load Component
- S** = Required Applied Shear load Component
- T<sub>ulsd</sub>** = Ultimate Limit State Tensile capacity
- S<sub>ulsd</sub>** = Ultimate Limit State Shear Capacity

7B SPECIFICATION STEPS SUMMARY:-  
 ULTIMATE LIMIT STATE DESIGN METHOD



## 7B ULTIMATE LIMIT STATE DESIGN METHOD

## WORKED EXAMPLE; LIMIT STATE DESIGN METHOD

<p><u>APPLICATION DETAILS:</u></p> <p><i>CALCULATED REQUIRED LOADING;</i>  <math>T = 6 \text{ Kn}, S = 8 \text{ Kn}</math></p> <p><math>E = \text{Edge Distance} = 105 \text{ mm}</math></p> <p><i>THERE IS A NEIGHBOURING ANCHOR 300mm AWAY REQUIRING SAME LOAD CAPACITY</i></p> <p><i>CONCRETE STRENGTH IS <math>&gt; 25 \text{ MPa}</math></i></p> <p><i>CONCRETE SUBSTRATE IS 300mm DEEP</i></p>	
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1) FROM SIMPLE LOAD TABLES; TRY M12 CHEMCAP ANCHOR.

2) ASSESS ANCHOR PULL OUT RESISTANCE;  $T_{acc} = T_{cfc} \times f_{cst} \times f_{aet} \times f_{adt} \times f_{ast}$

( $T_{acc}$  = CONCRETE RESISTANCE TENSION  $T_{apc}$  IN THE CASE OF CHEMCAP)

CHARACTERISTIC DESIGN CAP.;  $T_{cfc} = 20.53 \text{ Kn}$

CONCRETE STRENGTH FACTOR;  $f_{cst} = 1.00$

ANCHOR EMBEDMENT FACTOR;  $f_{aet} = 1.00$  AT EMBEDMENT OF 110mm (TRIAL)

CLOSE EDGE FACTOR AT 105mm;  $f_{adt} = 0.97$

CLOSE SPACING FACTOR 300mm;  $f_{ast} = 1.00$

$$T_{acc} = 20.53 \times 1.00 \times 1.00 \times 0.97 \times 1.00 = 19.91 \text{ Kn}$$

2) CHECK ANCHOR FAILURE IN TENSION; STEEL STRENGTH;  $T_{cfs}$

STANDARD ZP CHEMCAP STUD M12;  $T_{cfs} =$

3) ULTIMATE LIMIT STATE DESIGN TENSION;

$T_{ulsd} = \text{LOWEST CALCULATED VALUE OF; } T_{acc}, T_{apc} (= T_{acc}), T_{cfs}$

$= > 6 \text{ Kn}$  REQUIRED

Continued;

SEE SECTION 12; MACSIM CHEMCAP FOR ALL DATA USED

## 7B ULTIMATE LIMIT STATE DESIGN METHOD

## WORKED EXAMPLE; LIMIT STATE DESIGN METHOD

**APPLICATION DETAILS:**

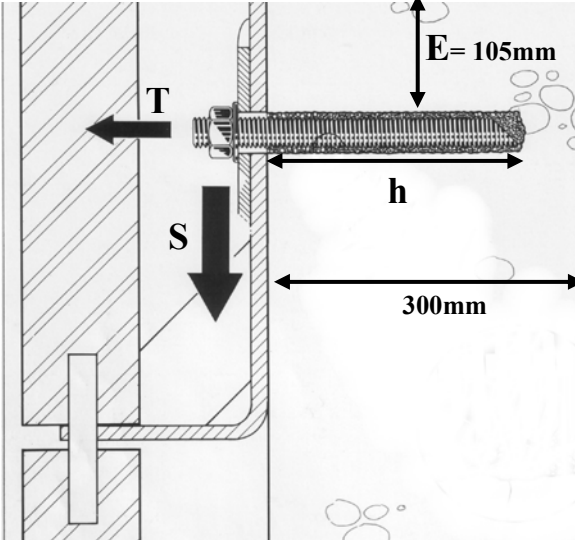
**CALCULATED REQUIRED LOADING;**  
 $T = 6 \text{ Kn}$ ,  $S = 4 \text{ Kn}$

$E = \text{Edge Distance} = 105 \text{ mm}$

THERE IS A NEIGHBOURING ANCHOR 300mm AWAY REQUIRING SAME LOAD CAPACITY

CONCRETE STRENGTH IS  $> 25 \text{ MPa}$

CONCRETE SUBSTRATE IS 300mm DEEP



- 4) CALCULATE THE CONCRETE EDGE RESISTANCE - SHEAR  $S_{acc}$

$$S_{acc} = S_{cfc} \times f_{css} \times f_{asds} \times f_{dls}$$

CHARACTERISTIC DESIGN CAPACITY CONCRETE EDGE  $S_{acc} = 4.50 \text{ Kn}$

FACTOR OF CONCRETE STRENGTH IN SHEAR  $f_{css} 25 \text{ MPa} = 1.10$

FACTOR OF SHEAR LOADING DIRECTION  $A^0$  OF  $0^0$   $f_{dls} = 1.00$

FACTOR OF EDGE AND SPACING FOR PAIR

$$f_{asds} = \frac{3E + S_p \times E}{6 \times E_{D(MIN)}} \times \frac{E}{E_{D(MIN)}} = \frac{(3 \times 105) + 300}{6 \times 55} \times \sqrt{105/55} = 2.57$$

$$S_{acc} = 4.5 \times 1.1 \times 1.0 \times 2.57 = 12.72 \text{ Kn}$$

$S_{cfs}$  ANCHOR CAPACITY SHEAR STEEL STRENGTH (M12 ZP) = 20.20 Kn

- 5)  $S_{ulsd} = \text{LEAST OF } S_{acc} \text{ AND } S_{cfs} = 12.72 \text{ Kn} (> 8 \text{ Kn REQUIRED})$

- 6) FINALLY CHECK THE COMBINED ULTIMATE LIMIT S

$$\text{MUST SATISFY } \frac{T}{T_{ulsd}} + \frac{S}{S_{ulsd}} < 1.2$$

$$6/19.9 + 8/12.72 = 0.94 \quad \text{OK}$$

**M12 CHEMCAP ANCHOR IS SUITABLE AND EFFICIENT IN THIS APPLICATION**

**SEE SECTION 12; MACSIM CHEMCAP FOR ALL DATA USED**