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Filling the Gap

A Practical Guide to Grouting

parchem

Contents

Introduction

The installation of machinery and securing structural steel to foundations are processes which at first may seem straight forward. Simply bolt the unit down to the foundation concrete – but this is rarely the case in real life. For example, the machine base may need to raised or lowered to match up with other equipment; the foundation may be uneven meaning a baseplate will only rest on the high points creating an uneven load distribution.

The purpose of a grout used in commercial or civil construction is to fill gaps and voids which we deliberately leave during construction to make placement of items possible without having to be too critical with say, the foundation or plinth on which the item is to be positioned. For example, the concrete foundation for a large electric motor will be cast perhaps 30mm lower than where the bottom surface of the motor base plate is going to sit; the motor is positioned and levelled using shims or levelling screws; and the nominal gap between the base plate and the foundation is subsequently grouted so that the weight of the motor is spread evenly over the whole area of the baseplate on to the foundation below. Well, that's how it should work in theory - unfortunately it is a little more complex in practice and failures sometime occur due to a variety of specification and site related issues.

This document aims to address many of these issues - both at the specification stage and at the application stage. Written in simple terms it is intended as a general guide to both specifiers and contractors and is based on general industry knowledge. It is not intended to serve as a project-specific resource as applications will necessarily vary based on a variety of factors, including site conditions and intended use. Specific advice on individual project installations should always be sought from grout suppliers such as Parchem Construction Supplies.

Reference is made in the document to the following Australian Standards:

AS 1478.2.2005

AS 1012.10 – 2000 and AS1012.11 - 2000

1.0 Selecting the correct grout

1.1 Definition of a grout

So we can begin with the same understanding, the following is offered as a definition of a grout:

A grout is a stable material which, after having been applied in a dry-pack, plastic, flowable or fluid state, will set to fill a void. After setting, the grout provides permanent, strong and total infilling of the original void to the required performance criteria.

Many of the terms used in this definition will be explored in detail throughout this document.

1.2 What is important when choosing a grout?

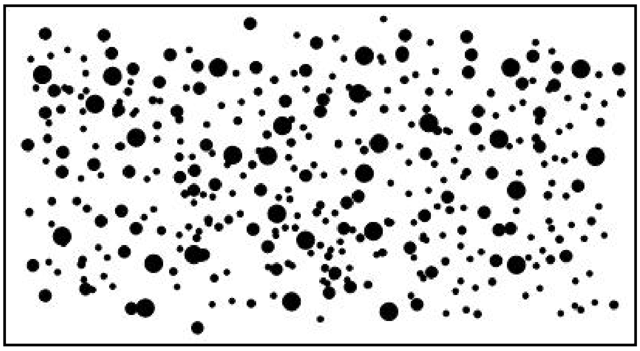
Before we consider the technical properties and the installation of grouts we need to be mindful of the particular project we are working on. It is important to ensure we don't under specify a product but also allow for the use of lesser performing products in less critical applications to provide a more cost effective installation. For example, while the grout used to install a multi-million dollar gas turbine needs to perform a similar function as a grout used under a tilt-slab wall panel - the cost difference between a high performance grout and a lesser performing grout is insignificant compared to the cost of shut-down and replacement of the grout if the grout under the turbine fails to perform.

Grout manufacturers like Parchem have broad ranges of grouting products to enable specifiers to select the correct grout for their particular application. There is no one grout that is appropriate for every application - so what is important to each application?

1.2.1 Effective Bearing Area (EBA)

The aim of most grouting applications is to evenly spread the weight and transfer the load of a machine being installed over the full area of its baseplate on to the foundation below. Achieving 100% Effective Bearing Area (EBA) is ideal but a figure which is rarely met. Although not covered in any Australian Standard, ASTM C1339-02 provides a guide to EBA where after a polymer (resin) grout is flowed under a plate and the grout hardens, the plate is removed and the grout surface wire brushed to expose any surface air bubbles or voids. A visual estimate is then made of the percentage of the grout top surface that is in contact with the plate. As part of the subsequent report the percentage bearing area is expressed as:

High (greater than 85%); Medium (70 to 85%) and Low (less than 70%)



Above; Visual guide of 85% EBA

Below: grouting of a bearing pad where only around 30% EBA was achieved with a cement based grout – fortunately the issues were investigated and rectified for the subsequent pours.

1.2.2 Shrinkage

In our definition at the beginning of this document, we mentioned "*total infilling of the original void*". If the grout we install under a base plate shrinks significantly, it is possible that the grout could shrink away from the underside of the baseplate and therefore would not be supporting the baseplate at all (in the worst case scenario). Shrinkage can also lead to cracking in the grout which can be detrimental to the installation.

Looking first at cement based grouts, these materials are essentially fine concretes - cement, aggregate and admixtures in a bag - to which we add water on site. Concrete shrinks - so does a cement based grout. What we need to do is minimise or compensate for this shrinkage, hence the term "Shrinkage Compensation". Rather than trying to totally eliminate shrinkage, we can limit it to a point where it becomes insignificant to the final result on site. Two types of shrinkage exist in cement based grouts - shrinkage in the "plastic" phase and "long term drying shrinkage" in the hardened phase of the grout. Several processes on site as well as admixtures within the material can contribute to minimising shrinkage in cement based grouts. They include:

Moisture loss during application - losing water from the mix during and after application will result in a volume change – shrinkage in the plastic phase. This can be limited by restricting unrestrained (open) surfaces to stop evaporation and by pre-soaking the concrete foundation to stop water in the grout being absorbed into dry concrete. Subsequent moisture loss during the curing of cement based grouts is also a problem and should be minimised with the use of curing compounds or wet hessian/burlap onto exposed surfaces once the grout has achieved initial set, then onto other surfaces once forms are stripped.

Gas generating admixtures - chemicals are formulated into the grout which react when the grout is mixed to produce small bubbles of gas (hydrogen or nitrogen) which essentially make the grout expand around 2% while it is still unset (plastic). This again is shrinkage compensation in the plastic phase. The gas does not affect the strength of the grout and generally occurs during the first 30 minutes after mixing/placing. These types of grout were previously known as Class A grouts (SAA Misc Pub MP20,Part3-1977). Some markets (underground mining in particular) are sensitive about hydrogen production in grouts due to the aluminium powder used in the grout to generate the gas. There is also a belief that hydrogen embrittlement may occur when a hydrogen producing grout is used near high tensile steel – using a nitrogen producing grout negates this.

Expansive cements - grouts in the higher performance spectrum will generally contain some amount of expansive cements which help compensate for shrinkage after the grout has set and initially hardened. This technology is normally aligned with gas producing expansion technology to produce what is known as "Dual Shrinkage Compensated" grouts. These grouts were previously known as Class A/C grouts (Class C if they only expanded in the set/hardened phase).

Shrinkage in resin based grouts – depending on the type of resin being used, shrinkage can be significant in resin based grouts. Polyester based formulations are quick to set but can exhibit up to 8% shrinkage which makes the technology unsuitable for most grouting applications. Well-formulated epoxy resin based grouts will only exhibit minimal shrinkage (around 1%), - but this could still be enough to create potential problems when used in large volumes and deep sections. Epoxy resin based grouts are generally formulated to be used within a range of gap sizes to ensure shrinkage is controlled. One of the features of epoxy based grouts is their ability to bond to the concrete foundation and the base plate. During the initial cure time of the grout when shrinkage is likely, the grout is likely to be bonded to the base plate and this will reduce the possibility of the grout shrinking away or even cracking under the base plate. Any tension built up at the time should "relax" out over time due to the plastic nature of epoxies. Experience has shown that even when shrinkage cracks occur in the unrestrained grout around the perimeter of a base plate grout, the cracks rarely continue for more than 20mm or 30mm under the baseplate.

The image on the left shows a significant crack in an epoxy grout which was initially a concern. However, investigation revealed the crack was only in the perimeter grout and didn't extend under the baseplate. The crack was later sealed with a low viscosity epoxy mix to stop water infiltration and for appearance's sake.

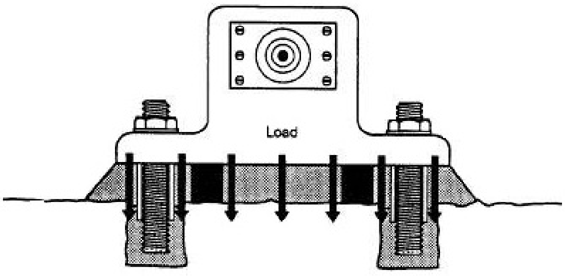
1.2.3 Strength

Grout strength is tested according to the Australian Standard AS1478-2005 and the figures quoted by manufacturers are established under controlled conditions which may differ from the results often reported for site prepared samples. There are several types of strength which relate to grouting which are described below in simple terms;

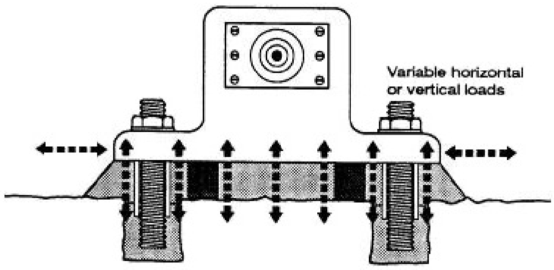
Compressive strength - the ability of the grout to resist the weight of the machine or item being placed on it; typically a static downward force. Most grouts these days will exceed 50MPa at 28 days, some reaching over 100MPa. A grout should achieve well above the compressive strength of the concrete is it placed on but there seems little advantage in placing 100MPa grout on 40MPa concrete foundations other than possibly the associated increase in tensile strength of the grout (discussed below). What can be more important is how quickly a grout gains its strength. Compressive strength development time is an important property particularly when turn-around times are critical to the project (for example in the case of machinery replacement). High Early Strength (HES) grouts can achieve over 30MPa in just 2 hours, which may be sufficient to allow a machine to go into service subject to the supervising Engineer's approval. However, HES type grouts may only achieve a 28 day strength of around 50MPa. High ultimate strength grouts, 90MPa plus, can be a compromise by achieving reasonable high early strength, perhaps 30MPa in 24 hours, while still achieving over 65MPa in 7 days.

Compressive strength of cement based grouts should be tested in accordance with AS1478.2-2005 (supersedes AS2073-1977) using maximum 75mm restrained metal cubes.

Tensile strength - the ability of a grout to hold together - not to break apart. One property is measured as Indirect Tensile Strength according to AS 1012.10 -2000. Depending on the application a grout may need higher tensile strength if the installation is subject to significant vibration or dynamic loads (as opposed to a static downward load). Such an application may be a drop forge or crane rails where there is a force cycling up and down or sideways forces being exerted.



Static load



Dynamic load

Whilst cement based grout can have high compressive strength, they will by nature have relatively lower tensile strength compared to epoxy resin based grouts which may be more suitable in these applications. The table below gives some comparative strengths representative of products in the market:

Grout Type	Compressive MPa @ 24hr	Compressive MPa @ 7 days	Tensile MPa @24hr	Tensile MPa @7 days
Cementitious General Purpose	25	45	2.9	4.7
Cementitious High Early Strength (HES)	40 (25MPa @ 2h)	**50**	**3.7**	**4.0**
Cementitious High Ultimate Strength (HS)	30	85	3.5	5
Epoxy Resin General Purpose	75	90	10	15

Tensile bond strength of epoxy grouts is also much higher than that of cement based grouts – the epoxy grout can virtually glue the baseplate to the concrete foundation (making any future removal of a machine much more difficult).

Strength in cement based grouts is achieved essentially by using high cement content (typically >50%) and mixing at low water to cement ratios. Varying the water content per mixed bag of grout is a useful feature of cement based grouts as it allows different consistencies of the grout to be achieved without significantly affecting the strength of the finished product (providing this is done within the scope recommended by the manufacturer).

Strength in resin/epoxy grouts is achieved by laboratory formulation of the raw materials - something which must be accurately carried through when using on site by ensuring products are mixed in their correct proportions. Epoxy grouts which are poorly mixed or mixed out of ratio, will not cure to their full potential strength and will often have a sticky surface. Although adding extra hardener may, up to a point make the epoxy set faster, the final cured product will be more brittle, reducing the dynamic load capability and because they are mixed our of ratio, the grout surface will remain tacky.

1.2.4 Workability

Different situations will require different methods of application of the grout. Some situations such as grouting under a wall panel or small base plate for example, will favour installation by dry packing or trowelling in the grout. Larger baseplates typically will best be grouted using a flowable consistency grout and formwork. The workability or consistency of the grout needs to match the requirements of the application.

Most cement based grouts have the ability to be used as dry pack (very stiff mortar) through to flowable consistency. The difference in consistency is achieved simply by varying the amount of water which is mixed with the dry powder. There will be an upper and lower limit to the amount of water which can be added to achieve the stated properties of the product and within each product the more flowable consistency will have a slightly lower strength than the stiffer mortar consistency – a result of the water to cement ratio changing.

Some of the higher end grouts will be more specific in their application and therefore more specific in their consistency. High Flow grouts are designed for use as flowable or fluid materials rather than trowellable mortars where they will tend to slump due to the plasticisers in the formulation.

The workability/consistency of cement based grouts should be measured in accordance with AS1478.2. There are three different tests depending on the target consistency required.

- The test for stiff mortar types uses a mechanical drop plate test to measure spread and slump, similar to a slump test for concrete. This test is referenced to ASTM C230.
- The test for a flowable grout uses a flow trough which measures the ability of a grout to flow a distance. This is a more relevant test for flowing grouts under baseplates.
- The test for a fluid grout uses a flow cone and measures the time taken for a specific quantity of grout to pass through the flow cone orifice. This is the test for maximum fluidity and only the highest performing grouts will pass this test without bleed water appearing.

Further information on these tests and interpreting the results is given in Section 4.

Retention of flow characteristics is sometimes overlooked but is often critical to achieving a successful installation. In the real world problems occur: pumps stop, breaks occur in the pouring process, etc. If a grout has good flow retention then the grout should be able to re-establish a flow once the problem is solved within a reasonable time. Grouts with poor flow retention will tend to gel if the flow is not continuous, and re-establishing flow of the grout will be difficult if not impossible.

On critical large grout pours, contingencies should be established prior to the work commencing in order to have a “plan B” if the grout stops flowing under a base plate for example. Strapping is a common problem solver; when the grout stops flowing, metal strapping is pushed into the grout and slowly worked through the grout to help re-establish flow. This can be a simple yet effective solution. Under no circumstances should vibrators be used to make the grout flow; these will “shock” the water out of the grout like bleed water from concrete and this water will accumulate below the baseplate, seriously compromising the effective bearing area.

Other things to consider

Chemical Resistance

Around 50% of the formulation of most cement based grouts is normal GP Portland cement, which is not resistant to common acids often encountered in processing plants. As such, cement based grouts are generally not suitable for grouting in these environments and epoxy based grouts are typically better choices where chemical resistance is required.

Cement based grouts in industrial applications may be over coated with chemical resistant epoxy coatings to protect the grout from chemical attack.

Temperature Resistance

Epoxy resin based grouts are generally not resistant to long term exposure to temperatures above 70°C unless they are specifically formulated for such an environment. Cement based grouts can typically handle much higher temperatures (up to 250°C), providing they have been properly applied and allowed to fully cure before exposure.

2.0 Specifying the grout to be used

It is important that any requirements for a particular grout are clearly set out in the project specification. Too broad a specification will allow inferior materials to be used and too narrow a specification can be time consuming for a contractor to track down the right product, unless it is nominated by brand and product name.

For example, a typical performance based specification for large equipment baseplates which have predominantly compressive loads would be:

1.0 Grouting Requirements

1.1 To the nominated area(s) (specify details and areas of application), grouting must be carried out using a pre-packaged, non-metallic and chloride free, dry powder blend of cements, graded fillers and chemical additives proprietary grout.

1.2 It is to be mixed with clean potable water to the required consistency. The plastic grout must not bleed or segregate. The storage, handling and placement of the grout must be in strict accordance with the manufacturer's instructions.

1.3 A positive volumetric expansion up to 3% shall occur while the grout is plastic by means of a gaseous, hydrogen free system. Additionally the grout is to be formulated to compensate for longer term expansion in the hardened state.

1.4 It shall exhibit Flow Characteristics when tested to AS 1478.2.2005 of 10 - 30 seconds using the flow cone procedure.

1.5 It shall be formulated to exceed the following characteristics when mixed with 3.7 litres water to one 20kg bag of the specified grout, at fluid consistency, when tested @ 23°C:

Compressive Strength (AS 1478.2.2005)	1 day 7 days 28 days	30MPa 45MPa 60MPa
Indirect Tensile Strength (AS 1010.10 – 2000)	1 day 7 days	2.5Mpa 4.5MPa
Modulus of Rupture (Flexural Strength) (AS 1012.11 – 2000)	1 day 7 days 28 days	3.0MPa 9.0MPa 10MPa

Conbextra® HF manufactured by Parchem Construction Supplies meets the performance criteria and is approved for this application.

A typical performance based specification for less critical grout under small structural steel columns would be:

1.0 Grouting Requirements

1.1 To the nominated area(s) (specify details and areas of application), grouting must be carried out using a pre-packaged, non-metallic and chloride free, dry powder blend of cements, graded fillers and chemical additives proprietary grout.

1.2 It is to be mixed with clean potable water to the required consistency. The plastic grout must not bleed or segregate. The storage, handling and placement of the grout must be in strict accordance with the manufacturer's instructions.

1.3 A positive volumetric expansion up to 3% shall occur while the grout is plastic by means of a gaseous system.

1.4 It shall be formulated to exceed the following characteristics when mixed with 3.8 litres water to one 20kg bag of the specified grout, at fluid consistency, when tested @ 23°C:

Compressive Strength	1 day	30MPa
(AS 1478.2.2005)	7 days	40MPa
	28 days	60MPa

Conbextra® GP manufactured by Parchem Construction Supplies meets the performance criteria and is approved for this application.

3.0 Installing Grouts

Based on the previous information we can now select the particular grout to be used and specify it either by name or by a generic performance based set of properties. Next comes the important stage of installation of the machine or item and the placement of the grout to give us the link between the two. The best grout in the world will not perform its task if the guidelines provided by the manufacturer are not followed. If any doubt exists on site regarding the product or process being used it is important to consult with all parties involved and then proceed with an agreed plan.

3.1 Preparation of the foundation

The concrete foundation or plinth on to which we are grouting our machine or similar item will generally have been cast weeks before the grouting is to take place. This allows the concrete to do most of its shrinkage and to stabilise as well as gain the strength required to support the machine. A minimum 28 days (4 weeks) should be allowed unless special concrete mixes are being used. The next step is to remove the laitance layer from the surface of the cured concrete. This is a weak layer which could affect the bond strength to the foundation – particularly important when dynamic loads are expected and epoxy grouts are being used.

There are several ways the laitance layer can be removed on site – some are acceptable; some are not. It is critical that the laitance layer is removed without damaging the concrete below. The end result should be a surface showing around 50% clean aggregate with no dust or loose material evident.

Chemical retarders / acid wash – these are definitely NOT acceptable methods of preparation. Whilst they may remove the laitance layer they may also still leave a relatively weak surface thereby compromising any ability for the grout to bond to the foundation.

Jackhammers – again using these is NOT an acceptable method of preparation. The aggressive impact of these tools will loosen aggregate and leave fine cracks in the concrete surface which could be detrimental to the grouting result.

Scabblers and Chipping guns – these are very effective methods of preparation. When used properly with the correct multi-point heads, these machines should produce a sufficiently low impact force which will easily remove the cement matrix without disrupting the aggregate in the concrete. Small hand units are available and larger units can be used for larger areas.

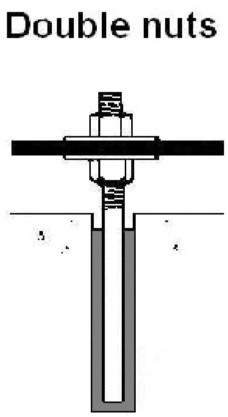
Captive Blast machines – these can be a very effective method of preparing large areas. Tiny steel "shot" are flung onto the concrete surface and the impact breaks away the weaker cement matrix leaving exposed aggregate. These machines are adjustable to meet most concrete strength and depth of removal required.

Typical captive blast machine

3.2 Machine / Baseplate Installation

More than 50% of grouting applications will involve grouting a baseplate or soleplate to a concrete foundation of some kind and for most of these the baseplate will first be positioned and levelled to the required height leaving a gap to be grouted. How the baseplate is levelled is one of those contentious issues of grouting. Following are several methods each with "pros and cons"

Threaded bolt with 2 nuts - this is a common way to level small baseplates in non-critical applications. The lower nut under the baseplate can be adjusted up or down to suit and the top nut is tightened to "sandwich" the baseplate into position.



Pro - easy to do; allows for infinite adjustment

Con - even after grouting, the weight of the machine is still resting mostly on the lower nut and the threaded bolt; post-tensioning is impossible (tightening the top nut just squashes the baseplate without tensioning it down)

Metal shim plates - a common process used to level large equipment. The machine is lifted and thin metal shims are placed under the baseplate on to the concrete foundation and the machine lowered on to the shims.

Pro - easy to do; allows for nearly infinite adjustment; greater weight distribution than "bolt and 2 nuts".

Con - unless the shims are removed after grouting, they will (like the bolt and 2 nuts) bear most of the weight; post tensioning is not possible unless the shims are removed (often not done!).

Plastic shim plates - same process as metal shims, however due to their "plastic" nature, plastic shims need not be removed as they will deform over time allowing all the weight to be taken by the grout.

Elastomeric blocks - not a system often used. Dense rubber blocks are put under the baseplate close to the holding down bolts and the machine is lowered on to them. They compress and take the weight, then final adjustment is made by tightening down the holding down bolts to compress the rubber further.

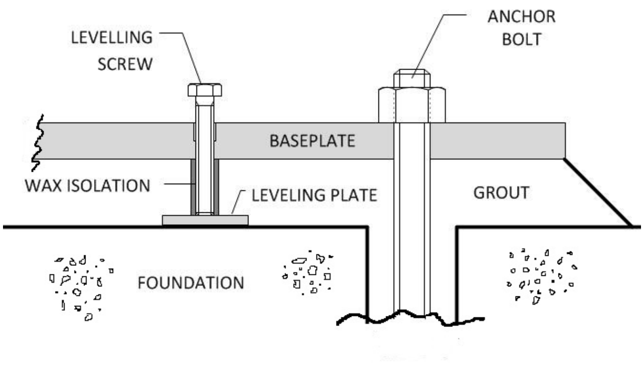
Pro - infinite adjustment, providing the correct density and size rubber block is used; the blocks can stay in place after grouting allowing post-tensioning

Con - care must be taken to ensure the rubber blocks don't cause deformation of the baseplate during tightening down against the rubber blocks

Levelling Screws (Bolts) – generally the best method. Threaded holes are made through the baseplate. Bolts are then threaded into these holes from the top and the tip of the bolt rests on metal pads positioned on the foundation. The bolts are turned up or down to achieve the correct level of the machine. The grout is then installed and when hard enough, the bolts can be backed out of the threaded holes leaving only the grout to support the weight of the machine. One of the steps necessary to make this process a success is to isolate the thread of the bolts from adhering to the grout (especially resin grouts) - this can be achieved putting petrolatum tape or wax paste around the bolt before the grout is placed.

Pro - infinite adjustment; the bolts are removed after grouting; post-tensioning is possible

Con – extra cost of tapping holes in the baseplate



Typical levelling screw arrangement

3.3 Anchor bolts

It is common practice for anchor bolt or holding down bolts to be grouted into preformed pockets as part of the grouting process. Epoxy resin based grouts or specialist anchoring products are best for this application, as they have greater bond strength and tensile strength than typical cement based grouts. It is important that the filling of the anchor pockets is done as a separate process prior to the general grout application to ensure the anchor pockets are filled without entrapping air.

If cement based grouts are being used for anchoring then the anchor pocket must be presoaked with water for at least 2 hours (preferably 24 hours) and the water vacuumed out just prior to the grout being placed. The anchor holes must also be undercut (tapered) or rough sided to provide mechanical resistance against pulling out. This is also the case when using polyester resin based anchoring systems which have limited bond strength and are prone to shrinkage.

Depending on the particular application and engineering requirements, there may be a requirement for the anchor bolts to be isolated from the grout and even from part length of the anchor material to allow for free stretch in the bolt when tensioned at the end of the installation. This can be achieved using foam pipe insulation or petrolatum wrapping tape or similar. Refer to the relevant design requirement on site.

3.4 Formwork

The method of installation (placement) will determine the extent and type of formwork required. Small baseplates which are being grouted using a “dry pack” method will only require basic formwork to be erected on the 2 back edges to provide a “stop” to pack the grout in against and then work forward. Trowel applied grouts will be similar to dry pack and both of these types of applications will typically be done using a suitable cement based grout.

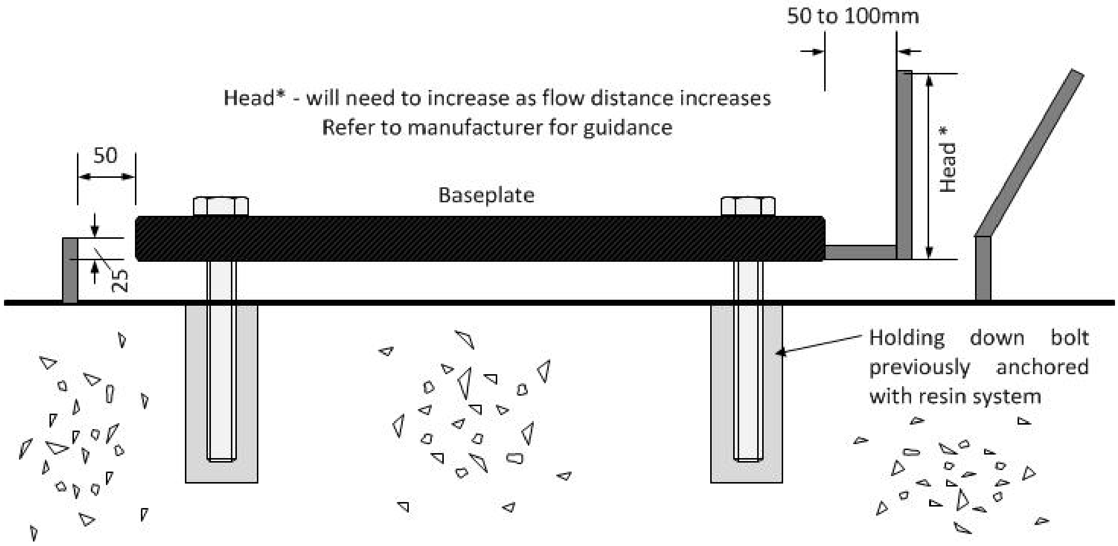
Flowable and fluid applications require much more complex formwork to achieve the desired result. The grout should be flowed in a single pass from one side of the baseplate to the other – ideally across the smaller dimension. The most common arrangement is a header box on one side into which the grout will be poured. Lateral formwork is then placed against the baseplate to direct the flow and maintain the head of pressure. At the side opposite the header box will be an exit form constructed approximately 50mm away from the baseplate which allows the progress of the grout to be monitored. For large pours it may be necessary to construct a moveable header box which can be moved along the length of the pour or have several header boxes and simultaneously pour the grout in. NEVER attempt to pour grout from more than one side unless the pour has been well planned with air relief holes positioned in the baseplate as this is likely to trap air under the baseplate.

Formwork materials – it is important that once the installed grout has set, any formwork can be easily removed without damaging the grout. This is particularly the case with cement based grouts which will often be “stripped” before the grout has achieved significant strength. Good quality new form-ply can generally be used for cement based grouts without the need for form release agents. However, if the grout is found to be sticking to the formwork, a thin application of a quality form release should limit this. You must be careful not to allow form release agent to contaminate the prepared concrete foundation.

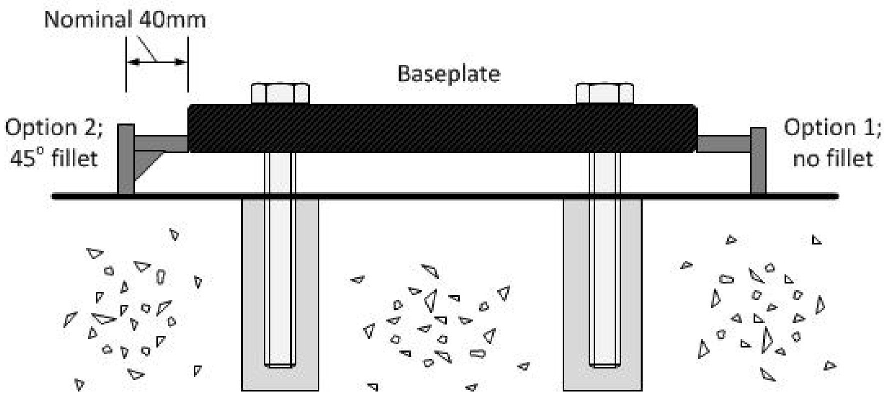
For epoxy based grouts is it often necessary to use a wax release to ensure bonding to the formwork doesn’t occur. Wax floor polish (solid type) is a good release agent which can be rubbed onto the forms during erection. Do not use liquids as these could run and contaminate the concrete foundation.

When it does come time to remove the formwork, use a gentle tapping action to protect the fresh grout which may still be relatively weak.

The following drawings are examples of formwork set ups when installing flowable / fluid grouts. There may be variations of these required on site depending on the actual configuration and shape of the installation but the basic principle remains to flow the grout via a header box on one side, under the baseplate in one flow to the opposite side.



Typical grout formwork set up



Typical lateral formwork arrangement

3.5 Pre-soak the substrate

One step in the process of installing cement based grouts which is often overlooked is pre-soaking the concrete foundation before applying cement based grout. This simple step can have a dramatic effect on the outcome. This only applies to cement based grouts; do NOT pre-soak when using resin based grouts.

Once the formwork is in place and any sealant applied had cured sufficiently, the formwork should be filled with clean potable water for a minimum of 2 hours, preferably 24 hours, before the grout is applied. This has three benefits:

Minimises moisture loss – the water added to the cement based grout occupies a volume when the grout is placed. If this water is lost into a dry concrete foundation during the initial setting of the grout then there is likely to be more shrinkage in the grout than expected and shrinkage cracks or voids may occur. Even with dry pack and trowel applications the concrete foundation should be dampened thoroughly before the application of any cement based grout.

Increased low properties – pouring a flowable or fluid cement based grout on to a dry concrete foundation will result in greatly reduced flow of the grout. The dry concrete will suck the mix water from the grout and cause it to false set at the interface greatly reducing the chance of the grout making it through to the exit side.

Increased bond – pre-soaking with water is critical to achieving the maximum bond strength to the concrete foundation.

During construction of the formwork, incorporate sealable outlets for the presoaking water to be drained out.

3.6 Mixing

Correct mixing of the grout is critical to the success of the total job. Sufficient man power and suitable equipment are essential.

Temperature considerations - All grouts should be stored (pre-conditioned) at suitable temperatures – typically above 10°C and below 30°C; ideal conditions are at 23°C. This not only protects the shelf life of the product but also improves the mixing and placement properties of the products. On site it can be difficult to meet these temperatures, especially in hot regions. Chilled water is often added to cement based grouts to help lower mixing temperatures. Products should be kept in shaded areas to lower mix temperatures. In cold regions it helps to store epoxy based products in heated rooms to improve mixing ability and flow properties. Care needs to be taken in hot regions. If the epoxy based grout is too warm then it will have a much shorter working time and may also develop an unacceptable peak exothermic temperature during curing, resulting in cracks in the cured grout.

Cement based grouts – the water to cement ratio in cement based grout is critical to the strength achieved and to the consistency required for the application. Water must be of drinkable quality (potable) and must be accurately measured in line with the manufacturer's guidelines. **Never** exceed the manufacturer's recommended maximum water addition. The water should always be poured into the mixing vessel first then the grout powder added while mixing progresses. Mixing time should be monitored with a stopwatch or clock to ensure sufficient time for the additives to begin working to produce the required final product – generally in the range of 3 to 5 minutes once all the powder has been added.

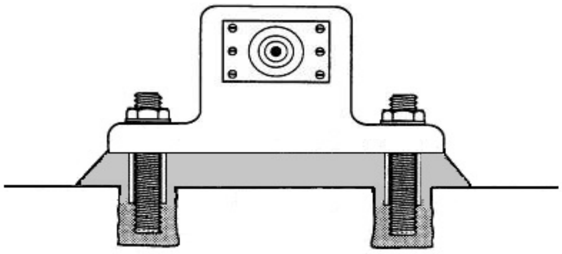
Epoxy resin based grouts – one critical aspect of mixing epoxy based materials is the mix ratio. Unlike cement based grouts where there is a range of water additions available to vary the consistency, epoxy based materials **must only** be mixed at the ratio supplied and as full kits – **all** of the base resin must be mixed with **all** of the hardener (as well as the filler component if using a 3 part mix). The other important aspect of mixing epoxies is to ensure a uniform mix is achieved throughout the mix volume. Poor mixing will leave a sticky resin at the surface and in the body of the grout, reducing the grout strength and other properties. Monitoring mixing time will help to ensure a good mix.

Mixing equipment - Various types of mixing equipment are available for cement based grouts, from simple 20 litre buckets and hand held mixers to complex high volume mixing machines with built in pumps for large projects. The important thing is that the mixer can shear the grout powder and water to produce a thoroughly mixed product. Free-fall type "concrete mixers" are generally not suitable and should not be used. BEWARE: some "grout pumps" are only suitable for cement slurry grouts containing no aggregate – these machines will generally not be suitable for many of the types of grout being discussed in this document due to the aggregate in the grouts. Mixing by hand is also not acceptable except for cement based "dry-pack" consistency applications. Grout manufacturers will be able to either supply suitable equipment or direct users to the appropriate suppliers taking into account the product being used and the volumes being installed. Most equipment suitable for cement based grouts will also be suitable for mixing epoxy based grouts.

Typical grout mixing equipment

3.7 Placement

The most simple way to place cement based grout in small volumes is to mix the product to a trowellable consistency, push the product into place under a baseplate and finish the edges, generally at a 45° slope from the bottom of the baseplates out onto the foundation as shown in the image below.



The grout should not extend up past the bottom of the baseplate in case the steel baseplate expands with heat, in which case the grout at the sides may crack away. Finishing at a 45° angle will help shed water away from the baseplate as well as improve the appearance of the finished installation and reduce sharp edges which may be prone to damage.

The same situation could be done using a "dry-pack" cement based grout. In this case the grout is mixed at a very low water ratio; just enough water for the grout to hold shape. The product is then rammed into place under the baseplate simply using a piece of wood and a hammer to build the grout out from formwork on the opposite sides. Generally formwork is required on 2 sides to build the grout out from.

Once the size of the baseplate increases (say more than 450mm square) it becomes viable to form up the area and pour or pump a grout into place. The extra work in erecting the formwork is offset by the speed in application of the pourable grout as well as the practicality of this method over trowel or dry-packing large areas of grout. As mentioned earlier, when flowing a grout under a baseplate it should be done in one continuous pour action, from one side only, until the grout emerges from under the baseplate on the opposite side. This helps ensure any air or residual pre-soak water is expelled and there is complete contact of the grout and the entire underside of the baseplate. During this process it is acceptable to gently "rod" the grout or use flexible strapping to help the flow, however with cement based grouts this activity should be kept to a minimum as excessive vibration of the mix could result in water segregating from the grout which will then accumulate under the baseplate and severely affect the effective bearing area. Vibrators should NEVER be used.

Pumping grouts through injection ports in a baseplate is possible providing it is well planned to ensure air pockets are not created. Pumping grout under baseplates horizontally is also acceptable; the hose should be inserted to the farthest point under the baseplate and slowly withdrawn as the grout is pumped in. This can also be a useful procedure to complete a failed grout pour where the initial grout pour has failed to reach the opposite side for some reason.

3.8 Curing and protection

When installing grouts in open areas, especially in the warmer months, consideration should be given to erecting temporary shades / tenting over the baseplate site to limit direct sunlight which can significantly increase the temperature of the baseplate and foundation.

Cement based grouts – as with any cementitious product it is important to protect the freshly installed grout from excessive loss of moisture which could lead to shrinkage and loss of strength. Maintaining the moisture content is particularly important for the first 7 days while the cementitious grout cures. This is best achieved with the application of a good quality curing compound or by keeping the surface damp with wet hessian on exposed surfaces after the grout has achieved its initial set then on the remainder of the grout once the forms are stripped. The baseplate along with the grout should also be protected as much as possible from extremes in weather – both hot and cold. Large volume pours of cement based grouts can generate significant heat from hydration; insulation from sudden cold temperature should be considered.

Epoxy based grouts - as with cement based grouts, epoxy grout installations should be protected from weather extremes during the first few days after application particularly when large volumes are involved and there is likelihood of exothermic heat evolving from the epoxy reaction. In hot regions, consideration should be given to carrying out large epoxy pours after sunset to take advantage of the cooler part of the day. Exposure to sudden cold night temperatures for example could cause the grout to crack during its curing phase. Insulation blanketing may need to be considered.

4.0 Meeting the Australian Standards

As previously mentioned there are Australian Standards for testing properties of grouting products which grout manufacturers should meet. The following is a summary interpretation of some of the key aspects of the current Australian Standards which relate directly to the performance of the products on site. It is not a substitute for, and should be read in conjunction with the relevant Australian Standards document.

AS 1478.2-2005 Consistency of Mixture with 7mm maximum aggregate. This part of the standard relates to how stiff or flowable a cement based grout is after mixing.

Interpretation:

Consistency	Range	Procedure
Stiff	<100% flow	Flow table, 5 drops in 3 sec
Plastic	100 – 125% flow	Flow table, 5 drops in 3 sec
Flowable	>30 sec 400 – 600 mm	Flow cone Flow trough
Fluid	10 – 30 sec	Flow cone

A stiff consistency is when the grout is formed into a flat cone shape on a flat table and the table is raised and dropped mechanically 5 times over a 3 second period and the amount of flow is observed. If the “cone” diameter increases by less than 100% of its original size, it is deemed “stiff”. This consistency would generally be suitable for dry-pack applications only. Under the same test if a grout had an increase in diameter between 100% and 125%, it would be considered “plastic”. This consistency would be suitable for trowel applications.

The flow trough is a relatively new test and involves measuring the distance a known volume (1 litre) of freshly mix grout will flow along a graduated channel (trough) under the influence of gravity. This test suits flowable grouts which may not have sufficient flow properties to be tested via the flow cone method. To meet the standard the grout needs to flow at least 400mm along the channel. This consistency is often sought on site for general flowable grouting applications over relatively short flow distances.

AS 1478.2-2005 Flow Trough

The flow cone test (shown on the right) is the most demanding test for the flowability of a grout. To meet the standard, a grout must flow through a 12.7mm hole at the base of a vertical funnel holding 1725ml of freshly mixed grout. If the flow is completed within the 10 to 30 seconds time, then the product is classified as “fluid”. This is the most flowable of all consistencies and is most likely to achieve long flow distances under baseplates.

AS 1478.2-2005 Test for Compressive Strength (Restrained or Unrestrained): This test establishes how strong a grout will be when mixed, formed, stored and tested under controlled laboratory conditions. The majority of well placed grout on site is under baseplates or similar restrained situations therefore it is sensible to test grouts in the restrained manner. The test involves placing the mixed grout into strong metal cubes (max. 75mm sides) which subsequently have a lid screwed on without any air gap between the underside of the lid and the surface of the grout. This enables the grout to develop strength as it would under a baseplate, which is especially important in the early phase of the grout setting when gaseous expansion may take place. If left to freely expand the grout would be unlikely to develop its target strength.

General comments on site testing

Unfortunately, on-site test cubes are sometimes made using weak materials such as formply (even old milk cartons) or the grout is not restrained nor cured under controlled conditions. Then the grout samples are sent away to a laboratory for compressive strength tests and sometimes the results from this testing indicates lower strengths than those published on product data sheets. From experience there are several factors which may contribute to lower than expected results from site prepared test samples:

Restraint – If you don't restrain the cubes during the plastic state expansion then you are likely to see about a 10% drop in compressive strength.

Sample dimensions – AS 1478 states samples must be maximum 75mm cubes. If the test is done for example using a 100mm dia x 200mm high cylinder the result is about half that of the cubes. That is, tall and skinny samples give lower results. And, you also get very poor results if the test faces of the samples are not perfectly parallel.

Curing – When testing to the standard, the samples are left in the moulds for 24 hours, then demoulded and placed into a lime saturated bath or a fog room, that is, perfect curing conditions. So if the samples are cast on-site, then transported to a lab without being protected from drying the results will be lower. Similarly if the samples are placed in normal water (not lime saturated) the water dissolves the lime out the hardened cement paste and the results are lower.

Transport - if the samples are cast on-site and then transported before final set is reached they can segregate and give poor results.

5.0 Product Reference and Information Sheets

Refer to the Parchem website www.parchem.com.au for the most up to date Technical Data Sheets

Conbextra® HF

High flow, dual shrinkage compensated, precision cementitious grout

Uses

Precision grouting of gaps from 10mm to 125mm, where high flow and extended flow retention time is required along with dual shrinkage compensation (previously Class A/Class C). Applications include grouting of:

- Critical baseplates and soleplates of large machines
- Load bearing structural columns
- Bridge bearing pads

Advantages

- Non-metallic dual expansion system compensates for shrinkage in both the plastic and hardened states
- Excellent initial flow and flow retention - for large and small grout pours
- Rapid strength gain facilitates efficient installation and operation of plant
- High ultimate strength and low permeability ensure durability of the hardened grout
- Hydrogen-free gaseous expansion, chloride free
- Suitable for pumping or pouring over a large range of application consistencies and temperatures

Description

Conbextra® HF, shrinkage compensated cementitious precision grout, is supplied as a ready to use dry powder. The addition of a controlled amount of clean water produces a free-flowing precision grout for gap thicknesses up to 125 mm. The low water requirement ensures high early strength and long-term durability.

Maximum aggregate size for pumping is 2.5 mm.

Supply	Yield (litres)		Typical 28 days strength (MPa)
20 kg bag	Stiff	10.40	77
	Plastic	10.70	64
	Flowable	10.80	62
	Fluid	10.90	60

Conbextra® C

High flow, dual shrinkage compensated, precision cementitious grout

Uses

General grouting of gaps from 10mm to 100mm, where high flow is required along with dual shrinkage compensation (previously Class A/Class C).   Applications include grouting of:

- Baseplates and soleplates of machines
- Structural steel column baseplates
- Voids between precast concrete and infilling blockwork

Advantages

- Dual expansion system compensates for shrinkage in both the plastic and hardened states
- High ultimate strength and low permeability ensure the durability of the hardened grout
- Can be dry packed / rammed, trowelled, flowed and pumped
- Hydrogen free gas expansion - minimises embrittlement
- Prepackaged material overcomes potential on-site mixing variations
- No metallic iron content to cause rusting

Description

General purpose shrinkage compensated cementitious grout, is supplied as a ready to use dry powder. The addition of a controlled amount of clean water produces a flowing shrinkage compensated grout for gap thicknesses from 10 mm up to 100 mm.

Maximum aggregate size for pumping is 0.3 mm.

Supply	Yield		Typical 28 days strength (MPa)
20 kg bag	Stiff	10.40	70
25 kg bag (NZ only)	Plastic	10.70	60
	Flowable	10.80	55
	Fluid	10.90	50

Conbextra® HS

High flow, high ultimate strength, dual shrinkage compensated, precision cementitious grout

Uses

Heavy duty precision grouting of gaps from 10mm to 125mm, where high flow and high ultimate strength is required. Applications include grouting of:

- Baseplates and soleplates of large machines subject to moderate dynamic loads
- Crane rail soleplates

Advantages

- Unique non-metallic dual expansion system compensates for shrinkage in both the plastic and hardened states
- Excellent initial flow / flow retention suitable for large or small grout pours
- Rapid strength gain facilitates efficient installation and operation of plant
- High ultimate strength and low permeability ensure durability of grout
- Hydrogen-free gaseous expansion
- Chloride free
- Suitable for pumping or pouring over a large range of applications

Description

Supplied as a ready to use dry powder. The addition of a controlled amount of clean water produces a free-flowing precision grout for gap thicknesses up to 125 mm. In addition the low water requirement ensures high early strength and long term durability.

Conbextra® HS is a blend of Portland cements, graded fillers and chemical additives which impart controlled expansion in both the plastic and hardened states. The filler grading minimises segregation and bleeding over a wide range of application consistencies.

Supply	Yield (litres)		Typical 28 days strength (MPa)
20 kg bag	Flowable	9.80	95
	High Flow	10.10	80

Conbextra® HES

Flowable, high early strength, shrinkage compensated, precision cementitious grout

Uses

Precision grouting of gaps from 15mm to 150mm, where fast setting and high early strength is required. Applications include grouting of:

- Critical baseplates and soleplates of large machines – particularly reinstalling equipment
- Load bearing structural columns
- Structural precast elements

Advantages

- Rapid strength gain facilitates rapid installation and operation of plant within a matter of hours
- High strength gain is achievable even at low temperatures
- Excellent initial flow and flow retention
- Unique system compensates for shrinkage in hardened state
- High ultimate strength and low permeability ensure durability of the hardened grout
- Chloride free
- Suitable for pumping or pouring over a large range of application consistencies and temperatures

Description

Conbextra® HES, rapid set high strength cementitious precision grout, is supplied as a ready to use powder. The addition of a controlled amount of clean water produces a free-flowing grout for gap thicknesses of 15 - 150 mm. In addition the low water requirement ensures high early strength and long term durability.

Maximum aggregate size for pumping is 5.0 mm.

Supply	Yield (litres)		Typical strength at flowable
20 kg bag	Plastic	10.00	2 hours : 25 (MPa)
	Flowable	10.20	8 hours : 35 (MPa)
			1 day : 37 (MPa)
			28 days : 50 (MPa)

Conbextra® Deep Pour

Flowable, precision cementitious grout for high volume and deep pours - (gaps 20 mm to 500 mm thickness)

Uses

Conbextra® Deep Pour is a Class A and C free flow precision grout for grouting gap applications ranging up to a maximum of 500 mm deep. Conbextra® Deep Pour is formulated to minimise segregation and bleeding for deep grout pours.

Advantages

- Non-metallic dual expansion system compensates for shrinkage in both the plastic and hardened states
- Excellent initial flow and flow retention
- High ultimate strength and low permeability ensure durability of the hardened grout
- Hydrogen-free gaseous expansion
- Chloride free
- Suitable for pumping or pouring over a large range of application consistencies and temperatures

Description

Conbextra® Deep Pour, shrinkage compensated cementitious precision grout, is supplied as a ready to use dry powder. The addition of a controlled amount of clean water produces a free-flowing precision grout for gap thicknesses up to 500 mm. In addition the low water requirement ensures high early strength and long term durability.

Conbextra® Deep Pour is a blend of Portland cement, graded fillers and chemical additives which impart controlled expansion in both the plastic and hardened states. The filler grading minimises segregation and bleeding over a wide range of application consistencies.

Maximum filler aggregate size contained in Conbextra® Deep Pour is 5.0 mm.

Supply	Yield (litres)		Typical 28 days strength (MPa)
20 kg bag	Flowable	10.00	60

Conbextra® UW

Flowable / pumpable, shrinkage compensated, cementitious grout for applications underwater

Uses

Grouting of gaps and concrete reinstatement where the grout needs to be flowed or pumped in underwater or in tidal zones. Unlike regular cementitious grouts, there will be no significant 'wash-out' of the cement phase. Applications include;

- Bridge columns
- Quay pillars
- Concrete piling
- Slipways and dams

Advantages

- No risk of significant 'wash-out' of cement phase when placed underwater
- Displaces water effectively
- Gaseous expansion system compensates for shrinkage and settlement in the plastic state
- High early and ultimate strength and exceptional resistance to freeze-thaw cycling ensure durability of the hardened grout
- Chloride free
- Pre-packaged needing only on-site addition of water

Description

Conbextra® UW is supplied as a ready to use powder. The addition of a controlled amount of clean water produces a free flowing grout. The grout exhibits exceptional resistance to 'washing-out' of the cement phase when placed in stationary or moving water.

Maximum aggregate size for pumping is 1.2 mm.

Supply	Yield (litres)		Typical 28 days strength (MPa)
20 kg bag	Flowable	11.60	50

FOSROC

Conbextra® GP

General Purpose, flowable, shrinkage compensated grout

Uses

Conbextra® GP is used for general purpose grouting where it is essential to eliminate shrinkage when completely filling voids or grouting between a base plate and substrate, e.g. grouting of a stanchion base plate. It can be used for anchoring a range of fixings such as masts and anchor bolts.

Advantages

- High ultimate strength and low permeability ensure the durability of the hardened grout
- Gaseous expansion system compensates for shrinkage and settlement in the plastic state
- Can be dry packed, rammed, trowelled, poured and pumped
- Pre-packaged material overcomes potential on-site mixing variations
- Develops high early strength without the use of chlorides
- No metallic iron content to cause staining

Description

Conbextra® GP, a general purpose shrinkage compensated cementitious grout, is supplied as a ready to use dry powder. The addition of a controlled amount of clean water produces a flowing non-shrink grout for gap thicknesses from 10 mm up to 100 mm.

Conbextra® GP is a blend of Portland cement, graded fillers and chemical additives which impart controlled expansion in the plastic state whilst minimising water demand. Low water demand ensures high early strength and graded filler designed to assist uniform mixing and produce a consistent grout.

Maximum aggregate size for pumping is 1.2 mm.

Supply	Yield (litres)		Typical 28 days strength (MPa)
20 kg bag	Stiff	10.60	75
	Plastic	10.70	70
	Flowable	10.80	65

Construction Grout

Economical, shrinkage compensated grout for general site use

Uses

Construction Grout is used for general purpose grouting when completely filling concrete voids or grouting between a base plate and a substrate e.g. the grouting of a stanchion base plate.

Advantages

- Gaseous expansion system compensates for shrinkage and settlement in the plastic state
- High ultimate strength and low permeability ensure the durability of the hardened grout
- Can be dry packed, rammed, trowelled, poured and pumped
- No metallic iron content to cause staining
- Prepackaged material overcomes potential on-site batching variations

Description

A general purpose shrinkage compensated cementitious grout, is supplied as a ready to use dry powder. The addition of a controlled amount of clean water produces a flowing grout for gap thicknesses up to 100 mm.

Construction Grout is a blend of Portland cement, graded fillers and chemical additives which impart controlled expansion in the plastic state whilst minimising water demand. The low water demand ensures high early strength. The graded filler is designed to assist uniform mixing and produce a consistent grout.

Maximum aggregate size for pumping is 0.3 mm.

Supply	Yield (litres)		Typical 28 days strength (MPa)
20 kg bag	Stiff	10.4	65
	Plastic	10.7	57
	Flowable	10.80	53

Conbextra® EP10

A highly fluid epoxy grout for grouting of small gaps

Uses

Conbextra® EP10 is a low viscocity epoxy grout ideal for grouting in small gaps between a base plate and substrate which needs filling and the structural load be uniformly distributed.

Also for use in conditions where chemical spillage may be encountered. Typical situations could be met in steelworks, refineries, electroplating works and chemical plants. Due to the low viscocity of Conbextra® EP10 it can be used to fill hairline cracks in concrete slabs from 0.25mm and upwards on horizontal surfaces using a gravity fed method.

Advantages

- High compressive, tensile and flexural strengths
- Resistant to repetitive dynamic loads
- Fast, convenient installation with early strength gain
- Withstands a wide range of chemicals
- Minimal shrinkage ensures surface contact and bond
- Low creep characteristics under sustained loading

Description

Conbextra® EP10 for grouting gaps ranging from 0.25 mm - 10 mm. It is an all liquid system consisting of a base and hardener.

Supply

Available in 3 pack sizes:
300 ml (2 component pack)
1.5 litre (2 component pack)
MTO 15 litre (2 component pack)

Typical 7 days strength (MPa)

83

Conbextra® EP65 Plus

A high performance multi purpose epoxy grout for dynamic/repetitive load applications

Uses

Conbextra® EP65 Plus is for use in situations where heavy dynamic or mobile loads are encountered. The gap between a base plate and substrate needs to be filled and the structural load be uniformly distributed, in such applications as reciprocating machinery, testing equipment, heavy crane and transporter rails, high speed turbines, centrifuges and drop forges.

Also for use in conditions where chemical spillage may be encountered. Typical situations could be met in steelworks, refineries, electroplating works and chemical plants.

Advantages

- High compressive, tensile and flexural strengths
- Resistant to repetitive dynamic loads
- Fast, convenient installation with early strength gain
- Withstands a wide range of chemicals
- Minimal shrinkage ensures surface contact and bond
- Low creep characteristics under sustained loading

Description

Conbextra® EP65 is an epoxy resin based product designed for free-flow grouting of gaps from 10-100mm.

Supply

14 litre (2 component pack)

Typical 7 days strength (MPa)

125 (at 23°C)

Conbextra® EP120

A high performance two part epoxy grout for dynamic/repetitive load applications suitable for large volume pours

Uses

Conbextra® EP120 is for use in situations where heavy dynamic or mobile loads are encountered. The gap between a base plate and substrate needs to be filled and the structural load be uniformly distributed. Applications include reciprocating machinery, testing equipment, heavy crane and transporter rails, high speed turbines, centrifuges and drop forges. Also for use in conditions where chemical spillage may be encountered. Typical situations could be met in steelworks, refineries, electroplating works and chemical plants.

Conbextra® EP120 is especially suitable where long working time and/or low exotherm properties are required e.g. for large pours or high ambient temperatures. It can also be used for grouting wide gap ranges making it a versatile product for a number of applications.

Advantages

- High compressive, tensile and flexural strengths
- Resistant to repetitive dynamic loads
- Fast, convenient installation
- Withstands a wide range of chemicals
- Virtually no shrinkage and hence ensures complete surface contact and bond
- Low creep characteristics under sustained loading
- Excellent flow properties
- Two part material giving a better quality control during mixing
- Can be used installed at high temperatures

Description

Conbextra® EP120 is unique two part epoxy grout formulation which does not require any additional aggregate to be added. This saves time and labour in the mixing process and provides a higher quality control in the mixing and placing of the grout.

Supply

14 litre (2 component pack)

Typical 7 days strength (MPa)

85 (at 40°C)

Conbextra® EP300DP

Low exotherm three part epoxy resin grout suitable for large volume pours

Uses

Conbextra EP300 DP is for use in applications where heavy dynamic or mobile loads are encountered. Particularly well suited to applications where long working time and/or large volume grouting is required.

Conbextra EP300 DP is also used to encapsulate piletops and ensure water tightness. The applied product is continuously bonded to the pile surface and prevents water seepage either through capillaries or along the reinforcement path. Applications include reciprocating machinery, testing equipment, heavy crane and transporter rails, high speed turbines, centrifuges and drop forges and pile head waterproofing.

Also for use in conditions where chemical spillage may be encountered. Typical situations could be met in steelworks, refineries, electroplating works and chemical plants.

Advantages

- High compressive, tensile and flexural strengths
- Resistant to repetitive dynamic loads
- Fast, convenient installation
- Withstands a wide range of chemicals
- Virtually no shrinkage and hence ensures complete surface contact and bond
- Low creep characteristics under sustained loading
- Excellent flow properties
- Can be used installed at high temperatures
- Wide range of gap thicknesses are possible

Description

Conbextra 300 DP is designed to be grouted into gaps from 10mm up to 300mm.

Supply

11.4 litre (3 component pack)

Typical 7 days strength (MPa)

85 (at 23°C)

For further information regarding grouting application, grouting and repair products, or construction tools and equipment, contact Customer Service on 1300 737 787 or visit www.parchem.com.au.

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