Grouting in the Construction Industry
1. INTRODUCTION

This guide covers the fundamental concepts and theories that apply to grouting in the construction industry.

It is instructive, informative and represents a benchmark for specifiers, designers, engineers and users.

1.1 TERMINOLOGY

**Grout:** A mixture of cementitious material and water, with or without aggregate, proportioned to produce a pourable consistency without segregation of the constituents; also a mixture of other composition but of similar consistency to fill a cavity for the purpose of filling it and which will subsequently harden to give specific physical properties.

**Chemical grout:** Any grouting material characterized by being a true solution, no particles in suspension.

**Particulate grout:** Any grouting material characterized by undissolved particles in the mix.

**Groutability:** The ability of a formation to accept grout.

**Grout cap:** A cap that is formed by placing concrete along the top of a grout curtain, often used in weak foundation rock to secure grout nipples, control leakage and form an impermeable barrier at the top of a grout curtain.

**Grout, colloidal:** Grout in which a substantial proportion of the solid particles have the size range of a colloid.

**Grout gallery:** An opening within a dam used for grouting or drainage.

**Grout header:** A pipe assembly attached to a ground hole, and to which lines for injection grout are attached, sometimes called (a grout manifold).
Grout mixture: The proportions or amounts of the various materials used in the grout, expressed by weight or by volume.

Grout nipple: A short length of pipe installed at the collar of the grout hole to facilitate drilling grout injection.

Grout take: The measured quantity of grout injected into a unit volume of formation, or a unit length of grout hole.

1.2 FUNCTION OF A GROUT

The function of a grout is to fill cavities. It is essential that the grout fills the cavity completely and permanently.

The shape, size and situation of the cavity will dictate:

• The method of grouting.
• The grout characteristics.

The reasons of filling the cavity will dictate the characteristics required of the hardened grout, such as:

• To provide or restore continuity of strength or transfer of load across the cavity (e.g. compressive strength)
• To provide a seal against either water ingress or passage into or across the cavity (e.g. water permeability)

1.3 GROUTING NEEDS

The following table is designed to describe what are the essential properties that grouts need to exhibit when applied in a particular way to fulfill a function in different situations to fill various needs.

Non-shrink and durable properties are essential to all cases described in the table.
<table>
<thead>
<tr>
<th>NEED/USE</th>
<th>GROUT FUNCTION</th>
<th>DELIVERY METHOD</th>
<th>ESSENTIAL PROPERTIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machinery /equipment Baseplate grouting</td>
<td>Load transfer, Levelling</td>
<td>Pouring, Pumping</td>
<td>Compressive strength, Impact resistance</td>
</tr>
<tr>
<td>Loadbearing elements Columns/beams Bearing pads</td>
<td>Levelling, Load transfer</td>
<td>Pouring, Pumping</td>
<td>Compressive strength</td>
</tr>
<tr>
<td>Post-tensioned cable ducts</td>
<td>Stress retention, Corrosion protection</td>
<td>Pumping</td>
<td>Compressive strength, Non-bleeding</td>
</tr>
<tr>
<td>Cracks in structures Fissures in rock</td>
<td>Waterproofing, Ground support</td>
<td>Pumping</td>
<td>Compressive strength, High bond strength</td>
</tr>
<tr>
<td>Voids around tunnel linings, pipes or submerged elements</td>
<td>Waterproofing, Consolidation</td>
<td>Pumping, Injection</td>
<td>Cohesive below water, Compressive strength</td>
</tr>
<tr>
<td>Permeable and unstable soils</td>
<td>Waterproofing, Consolidation</td>
<td>Injection</td>
<td>Low viscosity, Compressive strength, Water displacing</td>
</tr>
<tr>
<td>Anchors and fixings</td>
<td>Load transfer</td>
<td>Pouring, Pumping &amp; Injection or Capsule insertion</td>
<td>Compressive strength, Rapid setting</td>
</tr>
</tbody>
</table>
1.4 MECHANISM OF CEMENTITIOUS GROUTS

1.4.1 Grout Mix :
A grout mix may contain one or more of the following ingredients combined with water:

- CEMENT.
- EXPANDING AGENT.
- PLASTICIZER.
- FILLER.

The interaction between each of the ingredients gives the flow and mechanical properties of the fluid and hardened grout.

1.4.2 Types of Cement :
- Ordinary Portland Cements (OPC).
- Other types of cement as (Sulphate Resistant).

1.4.3 Bleed & segregation :
Bleeding is the flow of mixing water within, or its emergence from newly placed concrete, grout or mortar.

Segregation is the differential concentration of the components of mixed concrete, aggregate, or the like resulting in non uniform proportions in the mass.

Bleed & segregation are problems that commonly arise when excess water is added to site batched grouts in order to achieve the required flow.

Bleed & segregation are affected by different factors,

- Water/cement ratio.
- Aggregate grading.
- Gaseous expansion systems.

These factors are accounted for in the formulation of pre-packaged cementitious grouts.
As with all cementitious mixes, the ultimate strength of a cured and hardened grout is directly related to the W/C ratio. Clearly the requirements of high strength and flowability are directly opposing. The use of suitable plasticizer enables these opposing factors to be overcome. A plasticizer makes it possible to produce a grout which has good flowing properties and a high hardened strength.

1.4.4 Expansion:

As the grout hardens beyond the plastic stage, drying shrinkage occurs as a gradual process over a longer time period. The fundamental cause is that all cementitious materials shrink in volume as they dry. This longer term shrinkage can also lead to loss of contact with the underside of the base plate. Expansion or shrinkage compensation additives are used to overcome both plastic and drying shrinkage.

A commonly used expansion aid is finely divided aluminum flake. The reaction between aluminum and the alkaline pore water released from cement particles, generates hydrogen gas and hence the expansive force. It is important that the rate of gas generation is controlled so that expansion occurs gradually. The expansive force must be exerted while the grout remains fluid and continues up to the initial set.

Hydrogen embrittlement of high tensile stressed steel can be occurred, therefore a general trend towards the elimination of base metal additives is now being effective.

One alternative way of producing expansion is to use active carbon, because it will adsorb gases from the atmosphere onto their surfaces. When mixed with water it is claimed that these gases released to provide expansion.

Another method is to incorporate chemicals which produce nitrogen, and since the nitrogen is inert it could not lead to hydrogen embrittlement and the rate of reaction can be controlled.

In the hardened state it is necessary to generate some form of internal stressing to compensate for drying shrinkage stresses.
This can be done by using small particles of iron in the grout, where moisture causes oxidation of the iron. However further oxidation also causes rust marking.

Alternative additive are expansive cements which are based on calcium sulphoaluminate. On reacting with water, ettringite (calcium sulphoaluminate hydrate) is formed as long needle shaped crystals causing the internal stress that counteracts the forces of drying shrinkage.

It is important to understand that if a grout which contains a gaseous expansion system is allowed to expand freely with no-restraint there will be a loss in compressive strength of approximately 6% for every 1% of volumetric expansion.

The grouting process should ensure that a cavity is filled and the surfaces of the cavity will prevent the grout from expanding further. This restrains the grout so the strength is maintained.

When carrying out laboratory testing, it is essential that test cubes are fully restrained to prevent the expansion from occurring.

The efficiency of the expansion system in controlling cracking, which results from drying shrinkage, can depend on the degree and type of restraint provided.

1.4.5 Filler:

Fillers, in the form of graded sand, are included in the formulation of cementitious grouts in order to enhance flow characteristics and reduce shrinkage and cost.

Additional aggregate may be required to fill out the pre-bagged grout for use in large cavities in order to minimize potential exotherm.

To minimize the risk of (ASR), non-reactive aggregates should be used as crushed limestones.
1.5 MECHANISM OF EPOXY GROUTS

1.5.1 Epoxy Grout:
An epoxy based grout mix contains:
- EPOXY RESIN BASE.
- HARDENER.
- FILLER.

1.5.2 Resin Curing:
All epoxy resin systems depend upon mixing a predetermined quantity of a hardener with the base resin in order that the chemical reaction will occur. A temperature of 5°C or higher must prevail for continued chemical reaction.

The liquid resin has a chain-like structure with active centres on the chain. When the hardener is added it links across the active centres joining one chain to another to form a three dimensional network and thus changing the resin into a solid.

Depending upon temperature, this process produces a solid material within a few hours and about 90% of its ultimate strength after 24 hours at 20°C.

An epoxy resin grout is to be fully cured after 7 days at 20°C.

A resin which is fully mobile at a temperature of 20°C may become very slow pouring and slow flowing at 5°C.

A standard temperature response resin would present serious problems for grouting at low temperature so a special low viscosity temperature response resins will maintain full mechanical properties and good low temperature flow characteristics.
1.5.3 Function of Hardener:

The hardener component in an epoxy resin system has an important effect on the characteristics of the resulting grout.

The ratio in which the hardener is used with the resin must be exact. The chemical reaction generates exothermic heat during the early stage after mixing. In hot climates as the Middle East pre-cooling of the components, storing in air-conditioned areas and protection from direct sun-light are necessary.

Conversely, at low ambient temperature, materials should be maintained in a warm store (15 – 25°C).

1.5.4 Filler:

Inert fillers are incorporated in the mix in order to reduce heat output and cost, or give particular properties where large cavities are to be filled.

Fillers of the correct type, grading and strength form an essential part of the epoxy grouts.

The filler must always be added to the mixed liquid resin components.
2. GROUT TYPES

2.1 CEMENT AND SAND/CEMENT GROUTS

The simplest grout used in the construction industry is a mixture of cement and water. It is used where relatively small and narrow cavities need to be filled and where no load transfer is required. It is also used in soil stabilization.

There are however some disadvantages that are encountered:

- High shrinkage due to excess water.
- Poor flow properties.
- Unreliable strengths.
- Variable performances.

2.2 NON-SHRINK GROUT ADMIXTURE

When a plasticizing admixture with expansive properties is added to a sand/cement and water, higher mobility or flow will be obtained using less water.

The expansive action, normally imparted by an aluminum flake or active carbon.

There are advantages derived from this system:

- Improved flow and cohesion.
- Less water in the mix.
- Non-shrink.

But also there are some limitations:

- Variable performance.
- Variability of the raw materials.
2.3 PRE-PACKAGED CEMENT GROUTS

They are factory made grouts utilizing accurately measured amounts of controlled constituents. Such grouts give precise performance characteristics, both in fluid and hardened states.

Pre-packaged cement grouts may incorporate plasticizers to facilitate pouring and pumping; expansive agents to ensure that non-shrink characteristics, accelerators to improve early strength gains and the aggregate content to meet a range of cavity sizes and needs.

The advantages of such a system are:

• Precise strength, flow and shrinkage.
• Consistent performance.
• Pre-packaged. Convenient to use.
• Ability to eliminate segregation and bleed.

The limitations of using such a system are:

• Cost will be higher.
• Special mixing equipment is necessary for large jobs.
• Precise water conditions requirements.

2.4 RESIN BASED GROUTS

Resin based grouts are invariably factory-made materials utilizing either epoxy or polyester resins.

2.4.1 Epoxy Resin Based Grouts :

They consist of a base resin; hardener; aggregate (filler) as a 3-pack system. When mixed together, they create a strong, durable, high impact, chemical resistant and adhesives in their own right.
2.4.2 Polyester Resin Based Grout:

Polyester resins are generally faster reacting, more tolerant of temperature and water presence than epoxies. They do, however, shrink during curing and hardening so that their use is confined to highly filled mortar application such as anchoring and small area repairs.

The resin based grouts have the following advantages:

- High strength & impact resistance.
- Adhesive create bond between cavity surfaces.
- Non-shrink.
- Excellent flow characteristics.
- Pre-packaged and ready to use.
- High chemical resistance.
- Rapid strength gain.

The limitations of using such a system are:

- Higher costs.
- Temperature sensitive.
- Possible wastage.
- Risk of high exotherm.
- Mechanical mixing is essential.
- Need of a skilled operator is necessary.
3. SPECIFICATION FOR USE OF PRE-PACKAGED CEMENTITIOUS GROUTS

3.1 PROPERTIES, STANDARDS & BENEFITS

The grout shall conform to the following standards and shall fulfill these properties.

<table>
<thead>
<tr>
<th>PROPERTIES</th>
<th>STANDARDS</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength</td>
<td>BS 1881 Pt 116-83</td>
<td>55 N/mm² min</td>
</tr>
<tr>
<td></td>
<td>28 days at 20ºC</td>
<td>85 N/mm² max</td>
</tr>
<tr>
<td></td>
<td>Restrained cubes</td>
<td></td>
</tr>
<tr>
<td>Flexural strength</td>
<td>BS 4551-1980</td>
<td>8 N/mm² min</td>
</tr>
<tr>
<td></td>
<td>28 days at 20ºC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Restrained cubes</td>
<td></td>
</tr>
<tr>
<td>Early age expansion</td>
<td>ASTM C827-87 (at Final Set)</td>
<td>0% min</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4% max</td>
</tr>
<tr>
<td>Modulus of elasticity</td>
<td>ASTM C469-87a</td>
<td>25 KN/mm² min</td>
</tr>
<tr>
<td></td>
<td>28 days at 20ºC</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Restrained cubes</td>
<td></td>
</tr>
</tbody>
</table>

- The grout shall have positive expansion to compensate for plastic settlement shrinkage.
- The grout shall be free from bleed and segregation.
- The grout shall have sufficient workability to completely fill the grouting void without air pockets, depression or faults.
- The hardened grout shall be compensated for drying shrinkage by means of a proprietary shrinkage stress relieving system.
- If the gap thickness exceeds the maximum allowable thickness, then the grout shall be filled out with an approved dust-free aggregate.
Benefits of Using Pre-packaged Cementitious Grouts:

- Quality of product.
- Easier to use on site and to ensure full compaction beneath plate.
- Consistency of product in terms of strength and flow.
- Suitable for pumping or pouring over a large range of consistencies and temperature.
- Compensated for shrinkage in both plastic and hardened state ensuring uniform load transfer.
- Faster set time allowing for earlier steelwork erection & handover.

3.2 PREPARATION

- It is essential that both the concrete foundation and the base plate itself are in a good, clean condition before grouting takes place.
- The performance of the grout improves considerably when it is firmly in contact on both sides. This requires that both top and bottom sides to be clean. Grout tight formwork assist in maximum contact for best stress distribution.
- If grout leaks away after the grouting operation is complete, an air gap may form. The air gap will reduce the efficiency of the grouting.
- Pre-soaking benefits in that it maintains the grout flowability by preventing grout water being sucked into the substrate.
- Any water left standing in the shutter after pre-soaking should be removed with the use of a compressor or oil free air lance.
3.3 MIXING & PLACING

- Mechanical mixing is essential to attain the full effects of the plasticizer in the grout.
- The grout mixing paddle used with low speed drill, is suitable for small jobs.
- The grouting placing has to be carried out in a continuous operation or voids may result.
- The grouting can be done either by pouring or pumping.
- Sufficient material must always be available to ensure that a continuous supply of grout is maintained.
- **WATERPLUG** is an hydraulic cement fast setting cement base material, it sets in 1-2 minutes and it can stop grout leaking immediately.
- The grouting should not be poured from both sides of the plate as this will cause the void formation.

3.4 TESTING & CURING

- Areas which are left exposed should be cured immediately.
  - **KEMCURE** or **KEMCURE W** can be used.
- The exposed edges should be kept to a minimum.
3.5 METHOD STATEMENT

3.5.1 Preparation :

• The substrate should be clean, free from laitance, oil, grease and other contaminations.
• Bolt holes or fixing pockets must be blown clean of dirt or debris.
• The formwork shall be designed so that the grout must flow beneath the plate to reach the other side.
• Grout-tight formwork shall be erected that will not deform, deflect or leak.
• Formwork will be coated with a suitable mould release agent as (KEMREL) to enable easy removal of the shuttering.
• The area shall be flooded with fresh water several hours prior to grouting to saturate the concrete.
• All free standing water should be removed before grouting.

3.5.2 Application :

• The grout shall be mixed mechanically using an accurate pre-measuring water.
• The grout shall be poured into a 10 mm sieve to remove any lumps not broken down by the mixing process before pouring.
• The grouting shall be performed in a continuous operation until the void has been completely filled.
• Any leakage from the shuttering shall be immediately plugged with (WATERPLUG).
• After grouting is completed, the formwork shall be left in place for a minimum 24 hrs at above 10°C or 48 hrs at temperature 5 – 7°C.
• The exposed grout shall be cured with (KEMCURE).
4. SPECIFICATION FOR USE OF PRE-PACKAGED EPOXY GROUNTS

4.1 PROPERTIES, STANDARDS & BENEFITS

The grout shall conform to the following standards and properties. (at 20°C after 7 days).

<table>
<thead>
<tr>
<th>PROPERTIES</th>
<th>STANDARDS</th>
<th>SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strength</td>
<td>BS 6319 Pt 2</td>
<td>&gt; 80 N/mm²</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>BS 6319 Pt 7</td>
<td>&gt; 12 N/mm²</td>
</tr>
<tr>
<td>Flexural strength</td>
<td>BS 6319 Pt 3</td>
<td>&gt; 30 N/mm²</td>
</tr>
<tr>
<td>Shrinkage</td>
<td>ASTM C531-74</td>
<td>&lt; 0.2 %</td>
</tr>
</tbody>
</table>

- The grout shall have sufficient workability to completely fill the grouting void without air pockets, depressions or faults.

Benefits:
- Epoxy grouts are ideally suited to the high performance requirements of the cranes, rails, ports and harbor applications.
- Moving loads on a crane or rail truck subject the grout to alternate loads of compression, tension and shear caused by acceleration and braking.
- At ports and harbors there is a further risk of salt attack.
4.2 PREPARATION

• The foundation surface beneath the plates or rails shall be free from any oil, grease or loosely adherent material.
• Concrete shall be prepared by mechanical methods to remove any visible laitance or contaminations.
• Any steel surfaces shall be shot or sand blasted to remove rust and flaky mill scale.
• All surfaces must be dry with no free standing water.
• The formwork shall be leakproof and designed to give the correct head of grout for the flow distance and gap width, with stop ends at 5 – 6 m centres.
• All bolt pockets and sleeves shall be filled to within 25 mm of the top of the foundation prior to rail grouting.
• Grouting may commence immediately after the completion of the bolt pocket grouting.

4.3 MIXING & PLACING

• The grout shall be mixed mechanically.
• A continuous flow of the grout shall be maintained and shall be poured from one side to avoid air gaps.
• The grouting shall placed within the time constraints of each product.
• Any leak shall be stopped immediately with a plugging hydraulic cement base material (WATERPLUG) to prevent any loss of the grout.
4.4 TESTING & CURING

- On completion of the grouting, the exposed edges shall be protected during the curing period of the grout.
- For extra chemical resistance, epoxy paint can be used within 7 days.
- Testing moulds shall be 40 mm cubes complying with BS 6319 Pt 1.
- The testing moulds shall be carefully filled to avoid air entrapment without compaction.
- Testing shall be carried out according to BS 6319 Pt 2.

4.5 METHOD STATEMENT

4.5.1 Preparation

- All contact surfaces shall be clean and dry.
- Formwork shall be grout-tight, free from defects.
- Where necessary provision will be made for bleed points to enable air to escape from the gap that is being filled.
- Formwork shall be coated with a mould release to enable the easy removal and re-use of the formwork.

4.5.2 Application:

- The grout shall be mixed mechanically.
- The mixed grout shall be poured continuously from one side only and a hydraulic head should be maintained.
- Any leaks should be plugged immediately with (WATERPLUG).
- The grout shall be continued until the void has been completely filled.
- The formwork shall be left in place for 24 – 48 hours.
### 5. PRODUCT SELECTION GUIDE

<table>
<thead>
<tr>
<th>Product Name</th>
<th>Description</th>
<th>Theoretical Coverage Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ADMIXTURES</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>KEMGROUT AID</strong></td>
<td>is a powder admixture for cement grouts and concrete, combining a plasticizing agent and a gas producing expansion medium. The plasticizing agent allows the use of a low water / cement ratio with consequent high strengths and durability. The expansion medium counteracts the natural settlement and plastic shrinkage of the grout and aids stability &amp; cohesion. Sufficient restrained expansion is developed to ensure a high degree of interfacial contract.</td>
<td>0.225 kg is required for 50 kg of cement.</td>
</tr>
<tr>
<td><strong>KEMGROUT AID F</strong></td>
<td>is a blend of water soluble, high molecular weight white powder polymers for adding to cement grout mixes to use them in running water conditions without excessive wash-out of cement</td>
<td>0.270 kg is required for 300 kg of cement.</td>
</tr>
<tr>
<td><strong>PRE-PACKAGED CEMENTITIOUS GROUT</strong></td>
<td>A pourable cement base, non-shrink, hydraulic compound especially formulated for heavy duty support under machine base plate, cranes, rails ...etc. The material is a blend of Portland cement, pre-graded fillers and additives which impart controlled expansion in the plastic state whilst minimizing water demand. The low water requirements ensure high early strength &amp; long term durability. The filler grading is designed to aid uniform mixing and minimize segregation and bleeding.</td>
<td>2 kg/ m²/ 1mm thickness.</td>
</tr>
<tr>
<td>Product Name</td>
<td>Description</td>
<td>Theoretical Coverage Rate</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td>KEMGROUT HD HISTORICAL</td>
<td>A pourable cement base, non-shrink, hydraulic compound especially formulated for use on historical building and ancient monuments. The material is a blend of Portland cement, pre-graded fillers and additives which impart controlled expansion in the plastic state whilst minimizing water demand. The low water requirements ensure high early strength &amp; long term durability. The filler grading is designed to aid uniform mixing, &amp; minimize segregation &amp; bleeding.</td>
<td>2 kg/ m²/1 mm thickness.</td>
</tr>
<tr>
<td>* PRE-PACKAGED EPOXY GROUT</td>
<td>is a solvent free, 3 component epoxy resin based product designed for Non-shrink, free flow grouting of gap width from 10mm. and over.</td>
<td>2 kg/ m²/ mm thickness.</td>
</tr>
<tr>
<td>KEMGROUT EP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>* CHEMICAL ANCHORS</td>
<td>is a solvent free 3-components epoxy based grouting to fix rebars and bolt into drilled or cast holes in concrete, with a remarkable vibration and impact resistance, a high pull and loading forces.</td>
<td>2 kg/liter</td>
</tr>
<tr>
<td>KEMGRIP EP</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6. FULL SERVICE SUPPORT

Prokem has built an excellent reputation by providing a high level of both technical and commercial support for its clients. This support ranges from its research and development to its technical office and client service office.

Prokem provides the best possible training, technical data sheets, training videos and CDs also it organize seminars, presentations and fairs so as to facilitate transfer of knowledge to clients.

Such contribution to the achievement of successful results reflects Prokem’s long-standing dedication to quality assurance.
Resin Mortar Bedding For Bridge Bearing Pads Issued By Trade Federation Of Specialist Contractors & Material Suppliers To The Construction Industry (Ferfa).

Resins-practical Applications issued by (Ferfa).

Precision Groutings In The Construction Industry issued by FOSROC international limited.
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