

# Phoenix<sup>®</sup> Cement

## Properties and applications



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better for the environment

This document summarises the general properties and applications of Phoenix® cement and is intended to be read in conjunction with the Lafarge cement product datasheet. However, it is not exhaustive and for more detailed advice, or where the properties of concrete are critical, specialist publications should be consulted.

For Health and Safety information please refer to the Lafarge Health and Safety datasheet.

## Description

Phoenix is the Lafarge cement brand name for bulk Portland-fly ash cement. This type of cement is designated in the British Standard for cement (BS EN 197-1<sup>(1)</sup>) as:

BS EN 197-1: CEM II/B-V 42,5N

This designation covers cement containing between 65 and 79% Portland cement clinker, 21-35% siliceous fly ash and 0-5% minor additional constituents.

Lafarge Cement Phoenix contains a minimum of 25% fly ash and is cement strength class 42,5 with normal (N) early strength development.

Phoenix is manufactured at a number of sites in the UK, either by controlled blending or inter-grinding the various constituents in such a way as to produce a homogeneous product. It is subject to the same rigorous production control as other BS EN 197-1 cements with independent third-party verification and carries a CE Mark. Phoenix has been available within the UK for more than 25 years and has been used successfully in many prestige construction projects.

## Properties

The properties of Phoenix are very similar to those of conventional Portland cement (CEM I), but there are some differences that need to be recognised.

### Fresh concrete

At the same cement content, concrete containing Phoenix will have a reduced water demand and hence the slump at a given water/cement ratio will generally be higher than for a Portland cement concrete.

## Ten reasons for using Phoenix

- 1 Quality assured CE Marked product
- 2 Lower embodied CO<sub>2</sub> than CEM I Portland cement
- 3 Single point ordering (compared to using separate ash and Portland cement)
- 4 Enhanced sulfate resistance
- 5 Reduces risk of Alkali-Silica Reaction
- 6 Reduced mixing times (compared to using separate ash and Portland cement)
- 7 Manufactured by Lafarge, the world's largest cement producer
- 8 Improves pumpability
- 9 Enhanced resistance to chloride ingress
- 10 Strength gain after 28 days

At constant slump however, the concrete will appear to be more cohesive and bleeding will be reduced. The rate of slump loss is also slower.

Perhaps the most noticeable feature of concrete containing Phoenix is that it will appear darker in colour than Portland cement concrete.

The setting time of Phoenix concrete will be increased by up to 2 hours, this may be even more pronounced in cold weather. Whilst this can be advantageous in large concrete pours, it may be more critical in other applications such as power floated floors.

### Hardened concrete

The strength development of Phoenix concrete is slower at early ages (less than 7 days) than for Portland cement concrete proportioned to achieve the same 28 day strength. However, the concrete will continue to gain strength after 28 days provided it is properly cured. The insitu strength of Phoenix concrete, particularly in thick sections, will also often be





significantly higher than for Portland cement concrete. It should be noted that the rate of heat generation and peak temperatures generated by Phoenix concrete are lower than for equivalent Portland cement concrete. This property is often utilised for construction of large concrete elements (see *Mass concrete/large concrete elements*)

For concrete of a given strength class ('grade') and similar aggregates, the elastic modulus is similar to Portland cement concrete although creep may be reduced.

## Durability

### Alkali-Silica Reaction (ASR)

The measures to be taken in order to minimise the risk of ASR are described fully in BRE Digest 330<sup>(2)</sup>. This document is also referenced by the current British Standard for concrete; BS 8500<sup>(3)</sup>.

The fly ash content (>25%) of Phoenix reduces the effective alkali content of the cement and the declared mean alkali content is only 0.60% Na<sub>2</sub>O eq. This compares with 0.75% Na<sub>2</sub>O eq for Lafarge bulk Portland cements (CEM I).

In practice, this means that higher cement contents can be used, without increasing the risk of ASR, if Phoenix is incorporated in concrete compared to using Portland cement (see below). Cement contents are usually limited to a maximum of 550 kg/m<sup>3</sup> except for highly specialised applications.

Aggregate reactivity	Maximum allowable cement content (kg/m <sup>3</sup> ) *	
	Phoenix	Lafarge CEM I
Low	550	550
Normal	550	465
High	415	330

\* Assumes no alkali contribution from sources other than the cement

Consequently, when high cement contents are required to achieve good structural strength, using Phoenix enables the concrete producer to balance this with minimal risk of ASR.

### Resistance to sulfate attack and aggressive ground

Due to its fly ash content (>25%), Lafarge Phoenix qualifies for the '+SR' suffix of BS 8500 and BRE Special Digest 1<sup>(4)</sup> and is thus designated as: CEM II/B-V+SR.

Phoenix is suitable for use in all ground conditions where BS 4027 Sulfate Resisting Portland Cement (SRPC)<sup>(5)</sup> would be used and it is subject to exactly the same limits on minimum cement content and water/cement ratio (see below). It should be noted that whilst the use of Phoenix in Design Chemical class DC-4m is not permitted, these ground conditions, combining high levels of sulfate with high levels of magnesium, rarely exist in nature.

Design chemical class	Min cement content (kg/m <sup>3</sup> )*	Max water/cement ratio*
DC-1	-	-
DC-2	320	0.55
DC-2z	320	0.55
DC-3	380	0.40
DC-3z	340	0.50
DC-4	380	0.35
DC-4z	360	0.45
DC-4m	N/A	N/A

\* For concrete containing 20mm max size aggregate

### Resistance to carbonation

For concrete of a given strength class, BS 8500 recognises that concrete containing CEM II/B-V cement, ie Phoenix, has equivalent resistance to carbonation to concrete containing other cement types in all carbonation classes (XC1, XC2, XC3/4).



**Resistance to chlorides**

Phoenix is inherently more resistant to the ingress of chloride ions than Portland cement. This applies both to chlorides originating in de-icing salts and chlorides from seawater and increases the corrosion protection of the concrete to the embedded reinforcement. In BS 8500, this is recognised by permitting the use of a concrete of a lower strength class for a given cover to reinforcement. The following illustration is extracted from BS 8500-1 Table A.5 for concrete exposed to chloride class XS1 and intended for a working life of at least 100 years.

Nominal cover to reinforcement (mm)	Minimum concrete strength class	
	Phoenix concrete	CEM I concrete
35+Δc	C 35/45	Not permitted
40+Δc	C 32/40	Not permitted
45+Δc	C 28/35	C 45/55
50+Δc	C 25/30	C/40/50
55+Δc	C 25/30	C 35/45
60+Δc	C 25/30	C 35/45
65+Δc	C 25/30	C 35/45

**Resistance to freezing and thawing**

Once again, BS 8500 considers that concrete made with Phoenix (CEM II/B-V) has equivalent resistance to freezing and thawing as concrete of the same grade made with other cement types. For exposure to severe conditions, air-entrained concrete is the preferred option. Air-entrained Phoenix concrete is possible to produce practically, but care needs to be taken in the selection of admixtures (see *Compatibility with admixtures*).

**Concrete Mix Design**

Concrete mix design using Phoenix cement is based on exactly the same principles as for concrete containing Portland cement<sup>(6)</sup>. There are however, certain slight differences that should be recognised. **Trial mixes are strongly recommended.**

**Workability and water content**

The fly ash component of Phoenix acts as a lubricant and reduces the amount of water required to produce a given slump. Typically the water reduction in the region of up to 10 litres/m<sup>3</sup> can be expected. The use of Phoenix can also improve the pumpability of concrete, both by its lubricating effect, and by reducing any tendency for water to separate from the concrete in the pump line and cause blockages. The fly ash particles in Phoenix are typically finer than those of Portland cement. This leads to a more cohesive (low bleed) concrete which is generally advantageous, but it is important that concrete is not too cohesive (see *Yield*) as it can lead to problems with finishing (see also *Slabs and floors*).

**Strength and cement content**

For a given water/cement ratio, Phoenix will achieve a lower 28 day compressive strength than Portland cement. Therefore, to achieve a specific concrete strength, the water/cement ratio must be reduced. Effectively, this means that the cement content for a given water content should be increased. Typically around 10% (but in isolated cases up to 15%) more Phoenix would be required when compared to Portland cement. It should be noted that the Phoenix concrete will however gain more strength after 28 days than the equivalent Portland cement concrete. Because of this strength gain after 28 days, there may be instances where specification of a 56 day strength could be appropriate. This would then lead to possible economies in cement content. Trial mixes are recommended to determine the 28-56 day strength gain.

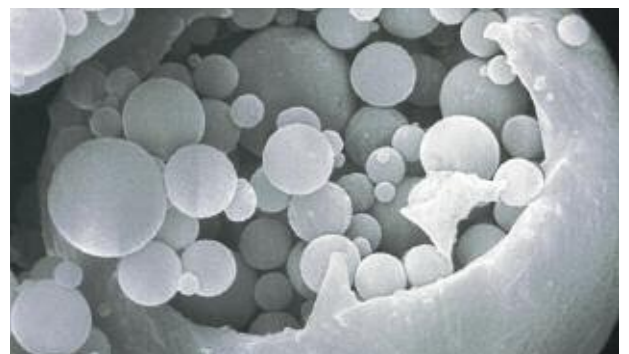
**Yield**

The particle density of fly ash (2300 kg/m<sup>3</sup>) is considerably lower than that of Portland cement (3150 kg/m<sup>3</sup>), consequently the volume occupied by 100 kg of Phoenix is greater than that occupied by 100 kg of Portland cement. In practice, this volume is offset by the reduction in water content and it is therefore normally unnecessary to make significant changes to the total quantity of aggregate required to maintain a constant yield.

Reductions in sand content (as a proportion of the total aggregate) can however, prevent the fresh concrete becoming too cohesive. When used in conjunction with coarse or poorly graded sands, Phoenix can act as a 'mix improver' by addition of fine material. In such cases, it may be appropriate to reduce the sand content by less than 3%, or not at all and maintain yield by a small adjustment in coarse aggregate.

**Compatibility with admixtures**

Phoenix is compatible with most commercially available concrete admixtures. However, when producing air-entrained concrete an increase in the dosage required to achieve the desired stable air content may be noticed. Alternatively, admixtures specifically formulated for use with fly ash cements can be selected.



*Electron micrograph of fly ash*

## Applications

Concrete containing Phoenix cement is appropriate for a wide range of construction applications.

### General construction

Correctly proportioned Phoenix concrete is suitable for most forms of general construction but proper attention must be paid to the curing process. The extended setting time and slow early strength development of Phoenix concrete requires extended curing and formwork striking times. This is particularly important for thin concrete elements (where heat loss to the environment is high) and construction in cold weather.

### Slabs and floors

Slab construction, particularly in hot or windy conditions, requires particular attention. Concrete made with Phoenix will remain plastic for longer times than Portland cement concrete and is generally quite cohesive. The extended setting time increases the time during which plastic cracking can occur<sup>(7)</sup> and the low bleed may increase the risk of plastic shrinkage cracking in particular. Adjusting the concrete mix to reduce the fines content (see *Yield*) or using a coarser sand will prevent the mix becoming too cohesive, allowing some bleed water to reach the surface.

***The importance of effective curing of exposed surfaces, as a means of minimising cracks, cannot be overemphasised.***

### Mass concrete/large concrete elements

The low heat evolution of concrete made with Phoenix is a significant advantage for the construction of mass concrete elements or other large concrete elements. Typically, the standard EN 196-9 heat of hydration (J/kg) of Phoenix is around 15% lower than for Portland cement. The use of a reduced heat cement helps to reduce the risk of early-age thermal cracking. For more detailed guidance, consult CIRIA report C 660<sup>(8)</sup>. The lower bleeding of Phoenix concrete is also helpful in deep sections as a means of reducing plastic settlement cracking.

### Concrete foundations

The reduced heat characteristics discussed above, when combined with the sulfate resisting properties of Phoenix concrete, make it particularly useful for constructing massive concrete foundations.

### Concrete exposed to seawater

As discussed in the section *Resistance to chlorides*, concrete made using Phoenix cement has enhanced resistance to chloride ion penetration and reinforcement corrosion. This gives it advantages for construction of concrete elements exposed to seawater.

### Mortar and screeds

Current standards<sup>(9,10)</sup> also permit the use of Phoenix in masonry mortars. It may also be used in screeds and concrete bases which will subsequently receive flooring<sup>(11)</sup> but is not permitted in cementitious wearing screeds (note: concrete made with Phoenix is permitted in directly finished concrete wearing courses<sup>(12)</sup>). Attention to proper curing is required for screeds to ensure that full performance is developed.

### Grouts

Phoenix is suitable for use in most general-purpose grouts, subject to any restrictions in the project specification. However, it should be noted that BS EN 447<sup>(13)</sup> restricts the cement type in grouts for pre-stressing tendons to Portland cement unless regulations in the place of use permit the use of other EN 197-1 cements.

### References

- 1 Cement – Part 1: *Composition, specifications and conformity criteria for common cements*. BS EN 197-1, 2000: BSI.
- 2 *Alkali – Silica reaction in concrete: Detailed guidance for new construction*. BRE Digest 330 Part 2, 2004: Building Research Establishment.
- 3 *Concrete – Complementary British Standard to BS EN 206-1*.  
Part 1: *Method of specifying and guidance for the specifier*. BS 8500-1, 2006: BSI.  
Part 2: *Specification for constituent materials and concrete*. BS 8500-2, 2006: BSI.
- 4 *Concrete in aggressive ground*. BRE Special Digest 1, 2005: BSI.
- 5 *Specification for Sulfate-resisting Portland Cement*. BS 4027, 1996: BSI.
- 6 *Design of normal concrete mixes* 2nd Edition. 1997: Building Research Establishment.
- 7 *Non-structural cracks in concrete*. Concrete Society Technical Report 22, 3<sup>rd</sup> Edn, 1992.
- 8 P. Bamforth. *Early-age thermal crack control in concrete*. CIRIA report C660, 2007:CIRIA.
- 9 *Code of practice for use of masonry – Materials and components, design and workmanship*. BS 5628 – 3, 2005: BSI.
- 10 *Specification for mortar for masonry – Part 1: Masonry mortar*. BS EN 998-1, 2003: BSI.
- 11 *Screeds, bases and in situ floorings – Concrete bases and cement sand levelling screeds to receive floorings – Code of practice*. BS 8204-1, 2003: BSI.
- 12 *Screeds, bases and in situ floorings – Concrete wearing surfaces – Code of practice*. BS 8204-2, 2003: BSI.
- 13 *Grout for pre-stressing tendons – Basic requirements*. BS EN 447, 2007: BSI.



## Lafarge Cement and Sustainability

Lafarge Cement UK has a long record of adopting an environmentally friendly approach. In 2007, this was recognised when Lafarge Cement UK won a prestigious *Business in the Community (BITC) Award for Excellence*. The Award recognises companies that are taking a 'strategic, comprehensive and innovative approach to reducing waste and natural resource use'.



As part of the Environmental Policy and the Environmental Management Systems established under ISO 14001, each works develops and implements a programme of continuous improvements in its environmental performance.

For the latest news on our progress to a sustainable future, visit our website: [www.lafargecement.co.uk](http://www.lafargecement.co.uk).

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