POZZOLANIC CEMENT

This document summarises the general properties and applications of Pozzolanic cement for use in situ concrete. Much of the information is also relevant to the production of concrete products. It is intended to be read in conjunction with the relevant Lafarge Tarmac Cement technical product datasheet.

This document 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 Tarmac Cement Health and Safety datasheet for Portland-fly ash cement.

1. DESCRIPTION

Pozzolanic cement is designated in the British Standard for cement (BS EN 197-1) as BS EN 197-1: CEM IV /B-V. This designation covers cement containing between 45% and 64% Portland cement clinker, 36-55% Pozzolanic material and 0-5% minor additional constituents.

Lafarge Pozzolanic cement typically contains around 45% siliceous fly ash (V) and is class 32.5 with normal (N) early strength development. It is also a certified low heat (LH) cement.

Lafarge Pozzolanic cement is manufactured by blending and intergrinding the various constituents to produce a homogeneous product. It is subject to the same rigorous production control as all other BS EN 197-1 cements with independent third-party verification and carries a CE Mark. It also carries the BS 8500 '+SR' suffix indicating sulfate resistance.

The reduced clinker content of Pozzolanic cement relative to CEM I, greatly increases the sustainability of the cement. The embodied CO2 of Pozzolanic cement is only around 55% of a typical Lafarge Tarmac CEM I cement.

2. USE IN BS 8500(2) CONCRETE

2.1 Designed Concrete

The use of CEM IV/B-V is permitted in all BS 8500 Designed Concretes, with the exception of concrete exposed to XF3 and XF4 freezing and thawing conditions (see section 4.5) and concrete exposed to DC-4m aggressive ground conditions, typically contaminated brownfield sites (see section 4.2).

2.2 Designated Concrete

The use of CEM IV/B-V is permitted without restriction in BS 8500 Designated Concretes GEN 0 – GEN 3, RC 20/25 and FND 2, 2z, 3, 3z, 4, 4z.

It can be used in Designated Concretes RC 25/30 – RC 40/50 only if specifically permitted by the specifier. It is, however, not currently permitted in BS 8500 Designated Mixes PAV 1, PAV 2 and RC 40/50XF. (This could be mitigated by blending Pozzolanic cement with Lafarge Tarmac CEM I).
2.3 Standardised Prescribed Concrete
The use of CEM IV/B-V is not currently permitted in any BS 8500 Standardised Prescribed (ST1 – ST5) concretes. (This could be mitigated by blending Pozzolanic cement with Lafarge Tarmac CEM I).

3. PROPERTIES
The properties of Pozzolanic cement are very different from those of conventional Portland cement (CEM I), and these differences and their effects on concrete production and site practice must be recognised.

3.1 Fresh concrete
At the same cement content, concrete containing Pozzolanic cement 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.

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 Pozzolanic cement is that it will appear darker in colour than Portland cement concrete.

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

3.2 Hardened concrete
The strength development of Pozzolanic 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 in situ strength of concrete, particularly in thick sections, will also often be higher than for Portland cement concrete.

It should be noted that the rate of heat generation and peak temperatures generated by Pozzolanic cement concrete are considerably lower than for equivalent Portland cement concrete. This property is often utilised for construction of large concrete elements (see section 5.2).

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.

4. DURABILITY

4.1 Alkali-silica reaction (ASR)
The measures to be taken in order to minimise the risk of ASR are described fully in the current British Standard for Concrete BS 8500 and in BRE Digest 330.

The fly ash content (target 45%) of Lafarge Tarmac Pozzolanic cement significantly reduces the effective alkali content of the cement and the declared mean alkali content is only 0.40% Na₂O eq (as compared with 0.75% Na₂O eq for Lafarge Tarmac bulk Portland cements (CEM I)). In practice, this means that higher cement contents can be used, without increasing the risk of ASR, if Pozzolanic cement is incorporated in concrete compared with using Portland cement (see below). Cement contents are usually limited to a maximum of 350 kg/m³; except for highly specialised applications. See Table 1.

<table>
<thead>
<tr>
<th>Aggregate reactivity</th>
<th>Maximum allowable cement content (kg/m³)*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lafarge CEM IV/B-V</td>
</tr>
<tr>
<td>Low</td>
<td>550</td>
</tr>
<tr>
<td>Normal</td>
<td>550</td>
</tr>
<tr>
<td>High</td>
<td>550</td>
</tr>
</tbody>
</table>

* Assumes no alkali contribution from sources other than the cement.
Consequently, when high cement contents are required to achieve good structural strength, using Pozzolanic cement enables the concrete producer to balance this with minimal risk of ASR.

It should be noted that Pozzolanic cement is particularly suitable for concrete containing high reactivity aggregates and recycled aggregates (RA), where a minimum of 40% fly ash in the cement is recommended as a means of minimising the risk of ASR.

4.2 Resistance to sulfate attack and aggressive ground

Due to its high fly ash content (Target 45%), Lafarge Pozzolanic cement is highly sulfate-resistant and carries the BS 8500 ‘+SR’ suffix. Pozzolanic cement is suitable for use in all ground conditions where sulfate-resisting Portland cement would be used and typically with less onerous limits on minimum cement content or water/cement ratio (see below). It should be noted that while the use of Pozzolanic cement 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. See Table 2.

### TABLE 2

<table>
<thead>
<tr>
<th>Design chemical class</th>
<th>Mín cement content (kg/m³)*</th>
<th>Min cement content (kg/m³)*</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC-1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>DC-2</td>
<td>320</td>
<td>0.55</td>
</tr>
<tr>
<td>DC-2z</td>
<td>320</td>
<td>0.55</td>
</tr>
<tr>
<td>DC-3</td>
<td>380</td>
<td>0.40</td>
</tr>
<tr>
<td>DC-3z</td>
<td>340</td>
<td>0.50</td>
</tr>
<tr>
<td>DC-4</td>
<td>380</td>
<td>0.35</td>
</tr>
<tr>
<td>DC-4z</td>
<td>360</td>
<td>0.45</td>
</tr>
<tr>
<td>DC-4m</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>

* For concrete containing 20mm max size aggregate

4.3 Resistance to carbonation

The use of designed concrete containing CEM IV/B-V is permitted in all carbonation classes (XC1, XC2, XC3/4).

However, in the case of high carbonation risk (exposure classes XC 3/4), BS 8500 recognises that for a given concrete strength class, concrete containing CEM IV/B-V cement - i.e. Pozzolanic cement - may be more susceptible to carbonation. Hence a higher concrete strength class is required at low cover depths.

The illustration in Table 3 is extracted from BS 8500-1 Table A.5 for concrete exposed to carbonation classes XC 3/4 and intended for a working life of at least 100 years.

### TABLE 3

<table>
<thead>
<tr>
<th>Nominal cover to reinforcement (mm)</th>
<th>Minimum concrete strength class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CEM IV/B-V concrete</td>
</tr>
<tr>
<td>30+Δc</td>
<td>N/A</td>
</tr>
<tr>
<td>35+Δc</td>
<td>C 40/50</td>
</tr>
<tr>
<td>40+Δc</td>
<td>C 35/45</td>
</tr>
<tr>
<td>45+Δc</td>
<td>C 30/37</td>
</tr>
<tr>
<td>50+Δc</td>
<td>C 28/35</td>
</tr>
<tr>
<td>55+Δc</td>
<td>C 25/30</td>
</tr>
<tr>
<td>60+Δc</td>
<td>C 25/30</td>
</tr>
<tr>
<td>65+Δc</td>
<td>C 25/30</td>
</tr>
</tbody>
</table>

4.4 Resistance to chlorides

Pozzolanic cement 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 designed concrete of a lower strength class for a given cover to reinforcement. The illustration in Table 4 is extracted from BS 8500-1 Table A.5 for concrete exposed to chloride class X5) and intended for a working life of at least 100 years.

### TABLE 4

<table>
<thead>
<tr>
<th>Nominal cover to reinforcement (mm)</th>
<th>Minimum concrete strength class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CEM IV/B-V concrete</td>
</tr>
<tr>
<td>35+Δc</td>
<td>C 40/50</td>
</tr>
<tr>
<td>40+Δc</td>
<td>C 35/45</td>
</tr>
<tr>
<td>45+Δc</td>
<td>C 30/37</td>
</tr>
<tr>
<td>50+Δc</td>
<td>C 28/35</td>
</tr>
<tr>
<td>55+Δc</td>
<td>C 25/30</td>
</tr>
<tr>
<td>60+Δc</td>
<td>C 25/30</td>
</tr>
<tr>
<td>65+Δc</td>
<td>C 25/30</td>
</tr>
</tbody>
</table>

4.5 Resistance to freezing and thawing

BS 8500 considers that concrete made with CEM IV/B-V has equivalent resistance to XF1 and XF2 freezing and thawing conditions as concrete of the same grade made with other cement types. For exposure to freezing and thawing conditions, air-entrained concrete is the preferred option. Air-entrained Pozzolanic cement concrete is possible to produce practically, but care needs to be taken in the selection of admixtures. The use of CEM IV/B-V concrete is not currently permitted in severe, XF3 and XF4, freezing and thawing conditions.

5. CONCRETE MIX DESIGN

Concrete mix design using Pozzolanic cement is based on exactly the same principles as for concrete containing Portland cement. There are however, certain slight differences that should be recognised. Trial mixes are strongly recommended.

5.1 Workability and water content

The fly ash component of Pozzolanic cement acts as a lubricant and reduces the amount of water required to produce a given slump. Typically a water reduction in the region of 10-15 litres/m³ or more reduces the amount of water required to produce a given slump. The fly ash component of Pozzolanic cement acts as a lubricant and reduces the amount of water required to produce a given slump. Typically a water reduction in the region of 10-15 litres/m³ or more reduces the amount of water required to produce a given slump. This 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 Pozzolanic cement 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 5.3) as it can lead to problems with finishing (see also 6.2). To avoid excessive water demand and/or cohesion of the concrete produced, the use of unwashed crushed rock fine aggregate with Pozzolanic cement is not recommended.
5.2 Strength and cement content
For a given water/cement ratio, Pozzolanic cement will produce a significantly lower 28-day compressive strength than Portland cement. Therefore the free water/cement ratio required for a given concrete strength must be reduced. Effectively, this means that the cement content for a given water content should be increased. Typically around 30% more cement would be required for C 16/20 concrete when compared with Portland cement (but up to 40% for higher strength concrete). It should be noted that the Pozzolanic cement concrete, 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 exact 28 - 56 day strength gain, but around 20% strength gain has typically been observed in practice.

5.3 Yield
The particle density of fly ash (2300 kg/m³) is considerably lower than that of Portland cement (3150 kg/m³), consequently the volume occupied by 100kg of Pozzolanic cement is greater than that occupied by 100kg 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, Pozzolanic cement 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 5%, or not at all and maintain yield by a small adjustment in coarse aggregate (see Lafarge Tarmac Information sheet on Mix Design for Pozzolanic cement).

5.4 Compatibility with admixtures
Pozzolanic cement 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.

6. APPLICATIONS
Concrete containing Pozzolanic cement is appropriate for a wide range of construction applications.

6.1 General construction
Correctly proportioned Pozzolanic cement concrete is suitable for most forms of general construction but, as with all concretes, proper attention must be paid to the curing process. The extended setting time and slow early strength development of Pozzolanic cement 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. The use of temperature matched curing may be advantageous in determining the formwork striking times.

6.2 Slabs and floors
Slab construction, particularly in hot or windy conditions, requires particular attention. Concrete made with Pozzolanic cement will remain plastic for longer than Portland cement concrete and is generally more cohesive. The extended setting time increases the time during which plastic cracking can occur and the low bleed may increase the risk of plastic shrinkage cracking in particular. Adjusting the concrete mix to reduce the fines content or using 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.
6.3 Mass concrete/Large concrete elements
The low heat evolution of concrete made with Pozzolanic cement is of significant advantage for the construction of mass concrete elements or other large concrete elements. The standard EN 196-9 heat of hydration (J/kg) of Pozzolanic cement is certified as being less than 270 J/g. 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(5). The lower bleeding of Pozzolanic cement concrete is also helpful in deep sections as a means of reducing plastic settlement cracking.

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

6.5 Concrete exposed to seawater
As discussed in section 3.4, concrete made using Pozzolanic cement has enhanced resistance to chloride ion penetration and reinforcement corrosion. This gives it advantages for construction of concrete elements exposed to seawater.

6.6 Floors, Mortar and Screeds
Current standards(6,7) do not permit the use of Pozzolanic cement in masonry mortars. It may be used in concrete bases that will subsequently receive flooring(8) but is not permitted in either cementitious levelling screeds or wearing screeds(9). Pozzolanic cement could be blended with CEM I for use in these applications.

6.7 Grouts
Pozzolanic cement 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(10) restricts the cement type in grouts for pre-stressing tendons to Portland cement (CEM I) unless regulations in the place of use permit the use of other EN 197-1 cements.

REFERENCES
1 BS EN 197-1. Cement. Composition, specifications and conformity criteria for common cements.
7 BS EN 998-2. Specification for mortar for masonry.
8 BS 8204-1+A1. Screeds, bases and in situ floorings. Concrete bases and cementitious levelling screeds to receive floorings.
9 BS 8204-2+A2. Screeds, bases and in situ floorings. Concrete wearing surfaces.
10 BS EN 447. Grout for prestressing tendons. Basic requirements.
The information in this publication is accurate at the time of printing, but Lafarge Tarmac Cement reserves the right to amend details as part of its product development programme.