# Cementitious materials and early-age concrete strength

**Chris A Clear of MPA–BRMCA** **discusses the correlation between the use of cementitious materials and early-age properties of concrete containing composite cements.**

There is a range of cement and cementitious materials available in the UK, either as factory-made composite cements or equivalent combinations of CEM I (Portland cement) and additional materials added at the concrete mixer.

There is a growing demand to use these cements and additions as they will help reduce the environmental impact of concrete, may reduce cost and can be used to enhance durability. The most common additional materials, used either in factory-made or combination cements, are ground-granulated blast-furnace slag (GGBS), fly ash, limestone and silica fume.

It should be noted that none of these additional materials is usefully cementitious without an activator. The normal activator is provided by Portland cement or the Portland cement clinker component of a factory-made composite cement.

Pozzolanic or latent hydraulic additional materials, such as fly ash, silica fume and GGBS, are those that either react with, or are activated by alkali released by the hydration of the cement to form products that contribute to strength.

Limestone fines are not pozzolanic but act as additional nucleation points for cement hydration and so contribute a little to strength development.

## Cement and combination types

Table 1 shows the main cement and combination types available in the UK, together with the standard nomenclature and the main constituents. The pozzolanic cement with siliceous fly ash as the pozzolana at 11–35%, CEM IV/A-V, is included for completeness but is not used as the readily available CEM II/B-V, or equivalent CIIB-V combination, covers the same blend and is preferred.

In accordance with BS EN 197-1[1] cement is also categorised by strength class as well as cement type; these categories are shown in Table 2 where there are minimum limits to early-age strength and limits for 28-day strength. Cement strength is based on testing a standard mortar, one part cement to three parts sand at a water/cement (w/c) ratio of 0.5, thus there will be no direct relationship between cement strength and concrete strength where the mix proportions will be very different.

## Cement type and strength classes

It is also important to note that there is no unique relationship between cement type and cement strength class. For example in the UK:

- CEM I is available as 52,5 N and 52,5 R
- CEM II/B-V is available as CEM II/B-V 42,5 N and CEM II/B-V 32,5 R
- CEM II/A-L or LL is available as 32,5 R, 42,5 N, 42,5 R and 52,5 N
- CEM III/A is available as CEM III/A 42,5 L but where CEM I is used in combination with higher percentages of GGBS then the appropriate equivalent strength class would be 32,5 L
- CEM IV/B is available and where CEM I is used in combination with higher percentages of fly ash then the appropriate equivalent strength class would also be 32,5 L.

**Table 1 – Cement and combination types**

| Cement notation | | | Composition | | | | |
|---|---|---|---|---|---|---|---|
| **Cement type** | **Cement to BS EN 197-1** | **Combination to BS 8500[2]** | **Clinker** | **Fly ash** | **GGBS** | **Limestone** | **Silica fume** |
| Portland | CEM I | – | 95–100 | – | – | – | – |
| Portland fly ash | CEM II/A-V | CIIA-V | 80–94 | 6–20 | – | – | – |
| | CEM II/B-V | CIIB-V | 65–79 | 21–35 | – | – | – |
| Portland slag | CEM II/A-S | CII-S | 80–96 | – | 6–20 | – | – |
| | CEM II/B-S | | 65–79 | – | 21–35 | – | – |
| Portland limestone | CEM II/A-L or LL | CIIA-L or LL | 80–94 | – | – | 6–20 | – |
| Portland silica fume | CEM II/A-D | CIIA-D | 90–94 | – | – | – | 6–10 |
| Blast furnace | CEM III/A | CIIIA | 35–74 | – | 36–65 | – | – |
| | CEM III/B | CIIIB | 20–34 | – | 66–80 | – | – |
| Pozzolanic | CEM IV/A | CIVA-V | – | 11–35 | – | – | – |
| | CEM IV/B | CIVB-V | – | 36–55 | – | – | – |

**Table 2 – Cement strength classes in accordance with BS EN 197-1**

| Standard | Class | Compressive strength, MPa | | | |
|---|---|---|---|---|---|
| | | Early strength | | Standard strength | |
| | | 2-day | 7-day | 28-day | |
| BS EN 197-1 | 32,5 L* | – | ≥ 12,0 | ≥ 32,5 | ≤ 52,5 |
| | 32,5 N | – | ≥ 16,0 | | |
| | 32,5 R | ≥ 22,5 | – | | |
| | 42,5 L* | – | ≥ 16,0 | ≥ 42,5 | ≤ 62,5 |
| | 42,5 N | ≥ 10,0 | – | | |
| | 42,5 R | ≥ 20,0 | – | | |
| | 52,5 L* | ≥ 10,0 | – | ≥ 52,5 | – |
| | 52,5 N | ≥ 20,0 | – | | |
| | 52,5 R | ≥ 30,0 | – | | |

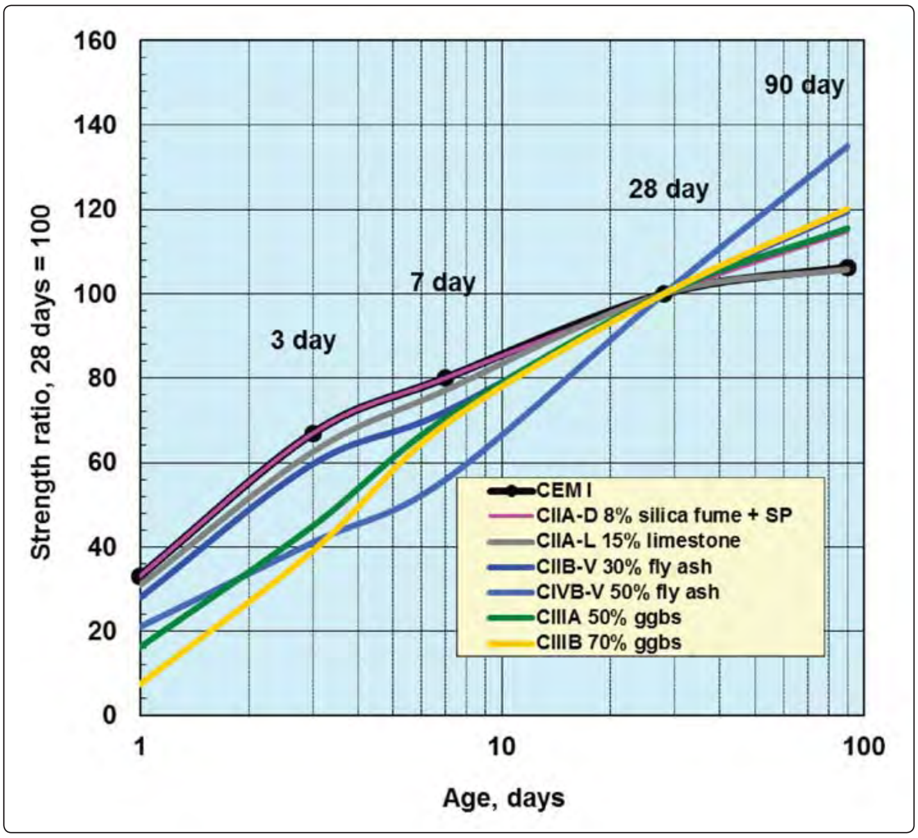


***Figure 1:** Comparative concrete strength development at standard 20°C water cure for the range of cements and combinations, at equal 28-day strength.*

It should also be noted that although these types and strength classes are available in the UK, the local availability should be confirmed if a particular type and strength class is required at commercially viable rates.

Although the cement types with the lowest amount of clinker and of the lowest strength classes are likely to require more time to set, stiffen and develop strength, there is no unique relationship as increasing the cementitious content and reducing the w/c ratio of the concrete may counter the effects of the lower-reactivity materials.

Figure 1 shows the comparative strength development of a range of concretes incorporating the various types of cementitious materials, on the basis of equal 28-day strength and standard curing. In overall terms the pozzolanic reaction of GGBS and fly ash does not really start until after a day or so, and so their contribution to concrete strength at one day is not

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significant. For example, in Figure 1 where 30% fly ash is used, the one-day strength is only around 70% of that achieved with CEM I, and similarly where 70% GGBS is used the one-day strength is only around 30% of that achieved with CEM I.

## Eurocode 2

Eurocode 2[3] Part 1-1, subclause 3.1.2 gives an expression for estimating the early-age compressive strength of concrete at 20°C, in terms of cement strength classes. It is apparent that where available it is preferable to use more specific data, noting also that the Eurocode 2 expression does not cover the use of low early strength cements, the 'L' cements from Table 2. For these reasons the expression is not particularly useful for application in the UK and reference to Figure 1 would be more useful.

The variation in early-age properties of concrete containing a range of cementitious materials should not be a barrier to their use to reduce environmental impact, material cost or enhance long-term durability properties. Where additional materials are used to replace significant proportions of CEM I, or the Portland cement clinker component of factory-made composite cements, then the effect on early-age properties may require some consideration to show that the required finishing or formwork striking times can be achieved. ●

**References**

1. BRITISH STANDARDS INSTITUTION, BS EN 197-1. *Cement. Composition, specifications and conformity criteria for common cements*. BSI, London, 2011.
2. BRITISH STANDARDS INSTITUTION, BS 8500. *Concrete. Complementary British Standard to BS EN 206-1. Part 1 – Method of specifying and guidance for the specifier. Part 2 – Specification for constituent materials and concrete*. BSI, London, 2006.
3. BRITISH STANDARDS INSTITUTION, BS EN 1992-1-1. *Eurocode 2. Design of concrete structures. General rules and rules for buildings*. BSI, London, 2004.