CONCRETING IN COLD WEATHER

This document provides information on the effect of low temperatures on concrete strength development and damage which may occur as a result of concreting in cold weather. Guidance is provided for producing and placing concrete in cold weather.

CONCRETE STRENGTH DEVELOPMENT IN COLD CONDITIONS

Cement hydration is the source of strength development in concrete. This reaction between cement and water generates heat. Like all chemical reactions, the rate of hydration of cement reduces in cooler temperatures. The strength development of concrete is influenced by a number of factors including mix design (cement content), cement type and temperature. The temperature of concrete has a significant impact on strength gain, and in Ireland where concrete plants are not typically equipped with facilities to manage the temperature of mix constituents, this is directly related to ambient temperature. Slender elements, particularly those with large surface area (slabs, walls etc.) tend to be more prone to heat loss, and hence prone to slow strength development in cold weather. Windy conditions exaggerate this effect even further.

At lower temperatures the rate of strength development reduces for all concrete mixes. **Figure 1** shows the effect of curing temperature on the compressive strength of structural grade concrete, with a mix design containing 330kg/m3 Irish Cement CEM II / A-L 42,5N (Normal Cement – Bulk) and a plasticising admixture. It should be noted that the strength development of mixes with lower cement contents will be impacted more severely than this.

The use of additions such as GGBS results in a slower rate of strength gain in the concrete. Cold temperatures further reduce this rate of strength gain. High levels of GGBS in concrete cause extremely slow strength development in cold ambient temperatures – the scale of this effect can be seen in **Figure 2** (overleaf).

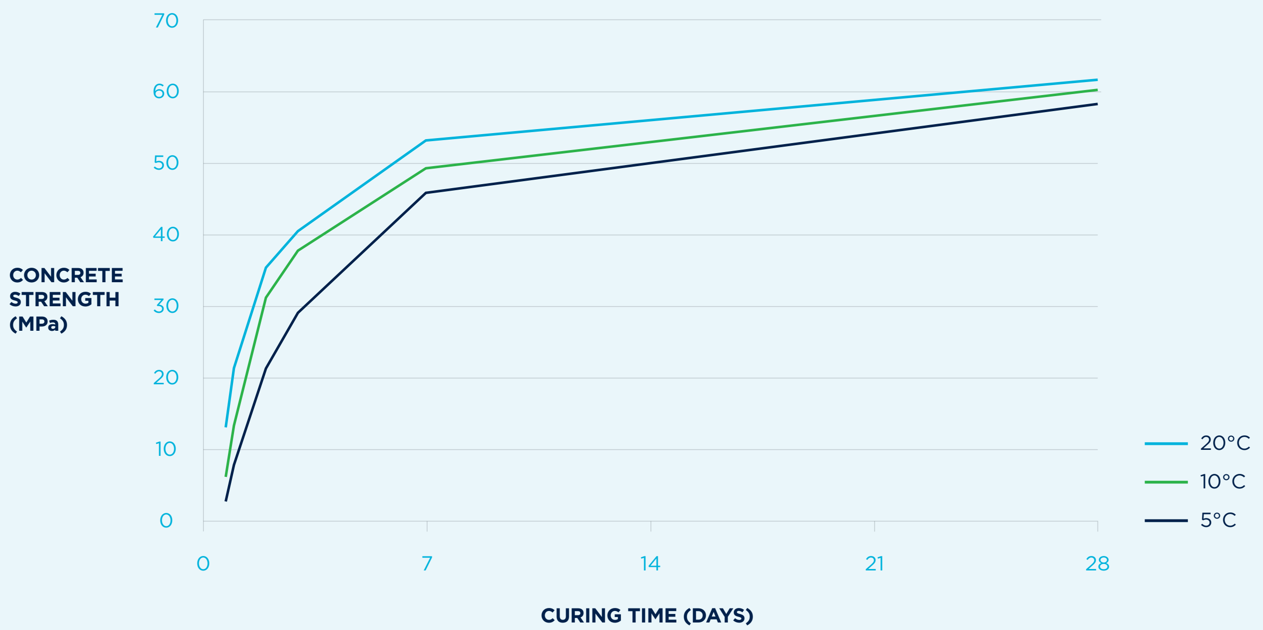

Figure 1: Effect of curing temperature on strength development of a reference concrete mix using Irish Cement CEM II / A-L 42,5N (Normal Cement – Bulk)

CONCRETE STRENGTH DEVELOPMENT IN COLD CONDITIONS

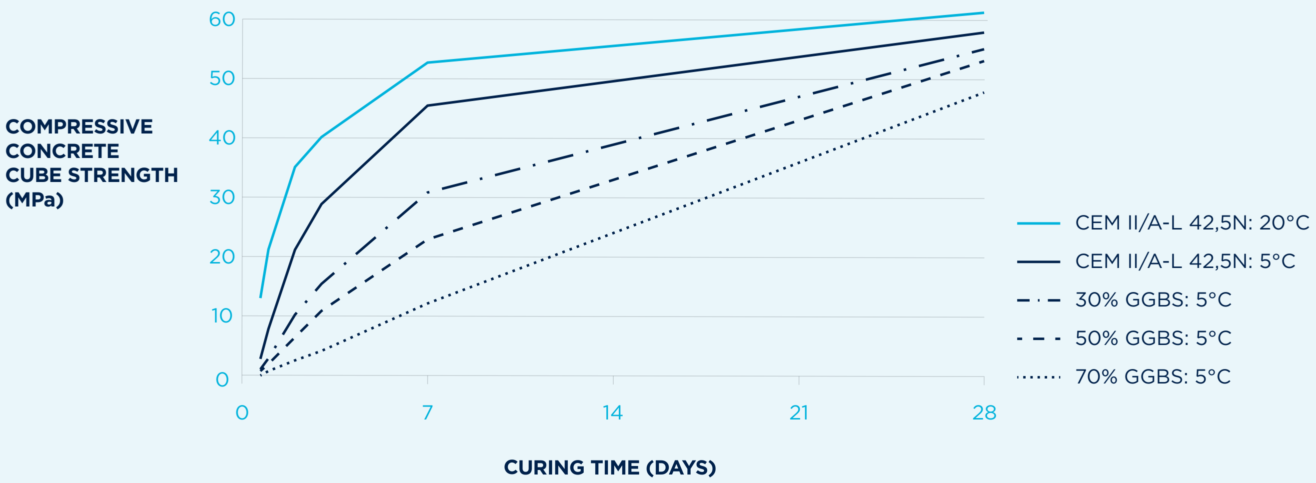

Figure 2: Effect of GGBS content on strength development at 5°C of a reference concrete mix using Irish Cement CEM II / A-L 42,5N (Normal Cement – Bulk)

DAMAGE TO CONCRETE CAUSED BY LOW TEMPERATURES

In its early life concrete can be damaged by rain, sleet, snow but perhaps the most severe climatic hazards are those caused by freezing temperatures and cold winds.

If **freshly placed concrete** is allowed to freeze, then the final concrete will be significantly damaged. Typically, fresh concrete that is allowed to freeze is disrupted to the extent that it will have to be immediately removed and replaced.

Young concrete which has stiffened but not gained enough strength is also at risk. Low strength concrete is not able to resist the disruption caused by expansion of water turning to ice in pores and voids in the concrete. Literature suggests that above 5MPa compressive strength concrete is able to resist these forces. Ultimately, young concrete will be permanently damaged if it is subjected to cold weather before it is strong enough.

Concrete of medium strength grade (or above) manufactured using Irish Cement CEM I or CEM II bulk cement, which is well compacted and is maintained at a temperature above 5° C for at least 48 hours, will normally be strong enough to resist frost damage. Concrete curing temperatures below 5° C will reduce strength development and increase the setting time of concrete. Slow strength development and longer setting times increase the period over which the young concrete is at risk of damage from low temperatures. Strong winds on exposed concrete can cause a rapid reduction in concrete temperature, even when the general conditions are not especially severe.

It's important to note that **Mature concrete** can also be damaged by cycles of freezing temperatures and subsequent thawing. I.S. EN 206 table NA.6 provides details of requirements for concrete mixes required to resist freezing and thawing. For freeze/thaw damage to occur there needs to be a critical level of moisture present in the concrete. Concrete subjected to freeze/thaw can result in defects such as surface scaling and pop-outs. Freeze/thaw damage to mature concrete can be extremely severe, particularly in concrete subject to its first freezing exposure.

COLD WEATHER CONCRETING GUIDELINES

GENERAL

- I.S. EN 206 requires that the temperature of concrete on delivery shall not be less than 5°C.
- Many specifications prohibit concrete placement when the ambient temperature reaches 5°C on a falling thermometer or is below 3°C on a rising thermometer. Exceptions are possible, however specialist advice should be sought in these instances.
- Concrete in slender elements (e.g. walls or slabs) which have large areas exposed to low temperatures, are most at risk. Concrete in slabs placed on cold ground is even more vulnerable to the risks associated with low temperatures.

CONCRETE PRODUCTION

- Aggregate stockpiles should be protected from frost, ice and snow. If possible, aggregates for immediate use should be stored in dry covered conditions. In particular avoid the inclusion of ice (in aggregates) into the mix.
- Water should be stored at temperatures well above freezing and supply lines lagged.
- Admixture data sheets for plasticisers should be checked to ensure that setting or early strength development will not be delayed at low temperatures for the design dosage levels. Precautions should be taken to prevent admixtures from freezing – see manufacturer's instructions.
- The use of CEM I 42,5R cement should be considered to increase the initial heat generated in the fresh concrete. Richer (stronger) mixes with more cement could also be considered.
- The use of high percentages of GGBS should be avoided in cold weather, as in sufficient quantities it will delay setting and early strength development, thus increasing the risk of frost damage.

TESTING CONCRETE

- Avoid adverse effects on samples and cubes in cold weather. Immediately after casting, store moulded cubes indoors in moist conditions at temperatures between 15°C and 25°C. After stripping, cure samples in water heated to between 18°C – 22°C, in accordance with I.S. EN 12390-2.
- The strength of cubes stored at low temperatures, even for a few days, is likely to lag behind the strength of cubes stored at a standard 20°C.
- Cubes simultaneously cast and stored with the structure can be used to give a good guide to early strength development in elements. This is referred to as 'temperature matched curing'.

PLACING / CURING OF CONCRETE

- Obtain weather forecast information to assist with planning. Bear in mind that localised conditions may be even more severe in exposed or elevated sites.
- In cold weather, with the risk of freezing conditions at night, there is increased risk if concrete is placed late in the day.
- Fresh concrete should not be placed on frozen ground or hardcore nor into shuttering which contains frost or snow.
- Concrete should be discharged and placed in its final position with as little loss of heat as possible and as quickly as possible. At low temperatures, concrete is likely to suffer heat loss in the order of 5°C between batching and placing.
- Concrete subject to low temperatures/frost/strong winds should be protected from heat loss by sufficient insulation, wind breaks etc. Frost blankets may be required in addition to insulated formwork. In all cases, care should be taken to avoid heat loss, thermal shock and unanticipated temperature gradients.
- In certain applications thermal curing can be used to maintain or increase the temperature of concrete which in turn improves the rate of strength development.
- Avoid wet curing of concrete when there is a risk of freezing.
- Full compaction is important, particularly in slabs, to remove excess air and water and reduce the risk of subsequent cold weather damage.
- At low temperatures, the rate at which concrete hardens is considerably reduced. There is a danger of striking formwork and supporting members before the concrete has acquired sufficient strength to support its own weight and the applied loads. Considerably longer striking times are required for concretes containing high GGBS contents. The effect of curing temperatures and GGBS on the early strength of concrete is shown in **Figure 3** (overleaf).

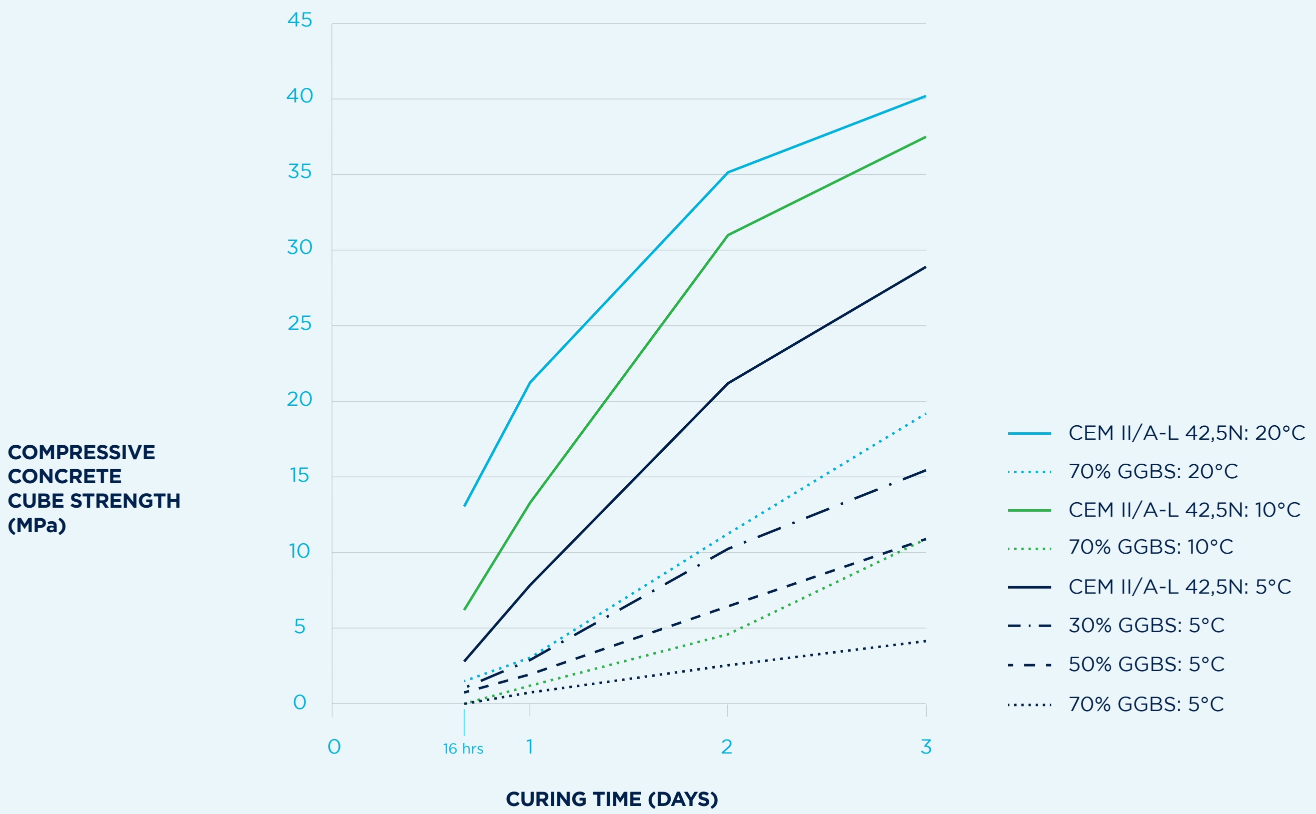

Figure 3: Effect of temperature on the early strength development of a reference concrete mix with varying percentages of GGBS

FURTHER INFORMATION

"Concrete Onsite 11 : Winter working. 11 pp. July 2015.
The Concrete Society, Riverside House, Camberley, Surrey, UK. www.concrete.org.uk

"Good Concrete Guide 8: Concrete practice, Guidance on the practical aspects of concreting" 85 pp. August 2016.
The Concrete Society, Riverside House, Camberley, Surrey, UK. www.concrete.org.uk ISBN 978-1-904482-90-1

Visit irishcement.ie for more information

Contact Irish Cement Technical Advisory service for more detailed information at 041 987 6000

Irish Cement
A CRH COMPANY

T 041 987 6000 E info@irishcement.ie W irishcement.ie