

What to do when prestressing in cold weather

by Paul Uno

The art of prestressing was first put into real form by innovators such as Eugene Freyssinet in the early 1900s. His most significant early bridge was the Pont le Veudre in France, built in 1911, which was unfortunately destroyed during World War II. Following this event Freyssinet wrote: "I have always loved it more than any other of my bridges, and of all that the war has destroyed, it is the only one whose ruin has caused me real grief."

Today we have achieved greater spans and thinner members using prestressing than Freyssinet could ever have imagined, primarily due to higher grades of steel and concrete. With today's low relaxation steel strand at an ultimate tensile strength (UTS) of 1870MPa, which is around three times higher than conventional reinforcing steel; and concrete grades in the range 50MPa to 100MPa (three to five times higher than in the 1920s), designers and engineers are able to produce aesthetically pleasing structures that have very light weight-to-span ratios.

In considering the difference between prestressed and post-tensioned systems, prestressed elements usually come in the form of precast units such as rail track sleepers, bridge beams or more



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commonly hollow core precast floor and wall panels. The latter are cast on beds up to 170m long where 12.7mm steel strands (formed from seven individual wires) have been tensioned earlier to about 85% of their 184kN breaking load. A machine then traverses along this bed placing, vibrating and tamping a very low water-cement ratio concrete mix over these strands (and the tubes that

form the hollows). Once the appropriate transfer strength has been reached, the panels are then saw-cut and removed from the casting beds.

Post-tensioning is where the same prestressing strands are tensioned after the concrete has been placed. Post-tensioning ducts are profiled on site (usually parabolic draping) and steel strands are then fed through these thin metal ducts. Concrete of grade 32MPa and higher is then poured around the ducts and the projecting cables at the dead ends (these are where the seven wires that form the strand are opened to form what are called onions, thereby anchoring the cable into the concrete matrix).

The next day the prestressing strands are tensioned to an initial force about 25% of the total jacking force which equates to 46kN for 12.7mm strands. This is done to control any shrinkage cracking that may occur during the first 24h. The concrete must have a minimum compressive strength of 7MPa or else crushing of the concrete may occur during stressing.

Once the concrete has reached a minimum air-cured compressive strength of 22MPa, the final force is applied to the strand (usually about 85% of the UTS



A photo of anchorage failure in cold weather.

which equates to 156kN). Again, the reason for the 22MPa concrete strength minimum is to ensure that the concrete does not fail around the anchor block during stressing. In very early UK documentation, a value of 3000psi was usually quoted which equates to 20.5MPa. Even though this is cube strength, not cylinder strength, it was a good starting point for us here but since then empirical results have pushed this lower bound limit to 22MPa cylinder strength.

It must be noted that the values of 7MPa and 22MPa only apply to 12.7mm strand and must rise to 9MPa and 25MPa respectively when 15.2mm diameter (250kN UTS) steel strand is used.

Even though cylinder strengths (standard water bath curing) are usually quoted on most jobs, air-cured cylinders are more appropriate for post-tensioned concrete. The reason for this is that a water-cured sample will achieve a higher compressive strength due to the favourable conditions of being in a water tank at $23\pm 2^{\circ}\text{C}$ (which promotes an ideal cement hydration and curing regime).

Quite often the concrete on site is not in a favourable condition due to the extremes of weather. This is of particular concern during winter conditions where morning temperatures can be quite low.

Research has shown that after three days at 23°C , concrete will achieve about 50% of its 28-day strength; however, when the temperature drops to 13°C , the three-day strength falls to about 30% of the 28-day value.

For a 40MPa characteristic strength mix at 28-days, the mean strength would be about 44-46MPa which translates to a three-day strength of about 22MPa (the value required to limit anchorage failure).

The photograph below shows what happens when tendons are stressed on a morning where the temperature is 6°C and the average ambient temperature for the three days prior to the pour had been 8°C . At $6-8^{\circ}\text{C}$, the concrete would have only achieved about 20% of its 28-day strength. For our 40MPa example earlier, this translates to about 8-9MPa.

This emphasises the need to leave cylinders air-curing on site from the time of pour to the time of tensioning, thereby ensuring a minimum 22MPa cylinder strength is achieved (when using 12.7mm strand).

It must also be noted here that just nominating a higher grade 28-day strength will not ensure an equivalent 22MPa at three to five days after placement (ie when most final tensioning is carried out).

Unless otherwise instructed, most mixes these days will contain supplementary cementitious materials (SCM), such as flyash. These materials are primarily added to ensure better workability, better longterm durability, better resistance to sulfate and AAR attack – but they will not assist in providing early age strength.

It takes time for the cement grains to react with the inert flyash particles in a pozzolanic manner to result in a better composite material.

In fact, some concrete suppliers in the eastern states are now using two SCMs (primarily flyash and slag) in their mixes, so the need to nominate a strength at the time of tensioning is paramount.

Concrete suppliers can easily modify the amount of all these SCMs to provide the appropriate three, four or five-day strength required for post-tensioning.

Communication between the design engineer and the concrete supplier prior to tensioning is therefore crucial to ensure the problems associated with prestressing during cold weather are minimised. ■