WEIRD AND WONDERFUL IN THE WORLD OF CONCRETE

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SYNOPSIS

Concrete is often perceived as a boring commodity, grey, cold and uninteresting. This paper sets out to challenge the myth with an exploration of the weird and wonderful uses concrete can be put to. By examining the use of concrete, its history and its use in actual projects, we will see the amazing versatility and complexity of the world’s greatest construction material.

INTRODUCTION

Its grey and it goes hard. Well it can be grey, or blue or green or brown, textured or polished (see photo opposite) and it will go hard at a time dependent on the materials we use. For most of the public it’s a very uninteresting commodity and how we could spend three days talking about it is quite incomprehensible! Yet this is the world’s most used construction material creating fantastic architecture (i) or simply the practicality of holding your washing line upright. In New Zealand, on average, each of you use around 1m³ per year. 2.4 tonne per man, woman and child. This is insignificant in world terms with projects such as the 3 Gorges Dam in China using 28 million cubic metres in construction.

The ability to alter the characteristics of the concrete in either its plastic state or its hardened properties is the key to its flexibility and ultimately its enormous use. The process of hydration, the products that are formed and the properties of the resulting solid conglomerate (ii) material can all be altered to give different properties. Concrete is thus the family name for a broad range of products formed from various cementitious materials (iii), aggregate types and admixtures.

The ability to mould concrete in its plastic state is one of its great advantages. It can be shaped to suit the wildest creations of sculpture or architecture.

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Its greatest advantage is its compressive strength in the hardened state. Use calcium aluminate cement and its possible to achieve remarkable compressive strength at an early age. For example 45 MPa in just 6 hours or 80 MPa in 24 hours! As well, it provides excellent acid resistance. 100 MPa using GP cement is now common. In 1994 a French firm Bouygues patented a Reactive Powder Concrete with compressive strength over 200 MPa and flexural tensile strength of 40 MPa.

We can leave it overnight and make it set the next day or combine it with accelerator in shotcrete and have it set immediately on the roof overhead. The weight can vary. It’s heavy enough to hold down pipes for the offshore oil and gas fields or light enough to float. It builds up significant temperature during its complicated hydration process, which can be a plus or a minus! Keep water in its pores and it will continue to gain strength for many years.

Probably its greatest weakness is that it’s not dimensionally stable once hard. It shrinks as water dries out but grows under temperature. Combine drying shrinkage with a relative weakness in tension and we get cracking – the bane of a concrete manufacturers life. But understand how to use the material, to work with its characteristics and it can last forever. Even some of the old Roman structures constructed using limestone cements are still around.

The oldest discovered concrete dates from 5600BC and was used to make hut floors for villages on the side of the Danube. This was some 2000 years before the Romans but when you look at their structures such as the Colosseum or the lightweight concrete dome of the Pantheon they were really developing and working with the benefits of concrete. An example of the early use of concrete in New Zealand is the Cornish pump house in Waihi. Constructed in 1904 with an extremely lean mix concrete the steam machinery powered a pump to dewater the underground mine workings. It was built right beside the 399m deep No 5 shaft and could shift 7000 litres per minute. This was quite a tourist attraction in Waihi but around 1999/2000 land subsided into the old mine workings which threatened the stability of the old pumphouse. So in 2005 Newmont, Hauraki District Council, Land Information NZ and the Historic Places trust decided to move it 1km to a new stable site. Building Solutions (who moved the Museum Hotel in Wellington) are currently working on the shift which is taking place in September this year. Some 800m³ of concrete is being used for the beams that will carry the pumphouse during its shift while a highly flowable concrete is being used to support the precast beams. 4m³ is poured each day and must reach 10 MPa by the next morning to enable the push to go ahead. This is in contrast to the very lean mix used in the original construction.
Portland cement was invented by Joseph Aspdin who took out a patent in 1824. His son William built cement works and the cement was sold by the barrel and often moved by ship. One ship was sailing down the Thames River when it ran aground. The locals quickly removed the barrels thinking they contained whisky only to find they held cement which by now had in fact set. They held a meeting and decided to build a pub from them which is still there today, the “Ship to Shore” in Sheerness (vii).

The Ready Mixed producers would be interested in a concrete mixer discovered in Northampton dated around 700AD. These were large dishes in the ground, of about 3m across, which were stirred by paddles attached to a beam which rotated around a central axis. This was pushed or pulled around by a number of men or animals on either side. One presumes the mixer was close to the construction site!

North of Auckland the Northern Gate Alliance are building the motorway from Puhoi through to the northern end of the existing motorway. This includes a twin tube tunnel as well as the bridge featured in last years NZ concrete conference. The interesting concrete here is the shotcrete. Obviously with shotcrete being shot overhead onto the roof of the tunnel it needs to set quickly so that it does not fall off. This is achieved through the use of accelerator being added to the mix at the nozzle. Prior to this the concrete is being delivered at around 140 – 160mm slump. Overnight the requirement is for the concrete to be delivered with a 10 hour life to enable work to proceed 24 hours a day without hold up. Trials on the delayed hydration mix are being carried out to ensure it meets the rigorous standards required. This has not been without hiccups with two solid concrete truck mixer bowls testament to the difficulty.

In Tauranga in 2005 Fulton Hogan undertook Stage 2 in the renovation and upgrading of The Strand, the main street facing the harbour. Included in this was the setting of a pump station into a large excavation which tended to fill with water on each tide. Fulton Hogan’s solution was to suspend the pump station by crane in the hole and then pour the concrete around it to create its foundation (ix). Of course the pump station needed to be well anchored prior to the next tide so early set and strength was needed, not to mention the cost of a large crane sitting while the concrete set. They wanted early strength but at the same time a highly flowable mix that could be delivered from the chute of the truck into the hole and flow through and under the Pump station. Sika’s HE20 superplasticiser was used to turn a stiff concrete on site into a highly flowable mix which then dropped slump quickly and was a stiff mix.
again in a very short time. This proved quick and efficient.

As Adam Neville says “The primary requirements of a good concrete are a satisfactory compressive strength and good durability.” Often that compressive strength is required quickly to suit the construction. For instance a recent example called for the concrete to be poured at 9am and to be 20 MPA in compression by 5pm. This was for a main Auckland road where a pipe needed concrete encasement to provide the load carrying capacity. This was achieved using a concrete mix incorporating HE cement content, superplasticiser and accelerators. A by product of hydration is heat release. This can be a positive or a negative. In the beam the heat build up meant the concrete gained strength quickly. What had not been considered was how to get the asphalt to set on a very hot subbase!

Certainly in any mass foundation or where high strength concrete is used temperature gain is an issue. The heat generated by the hydrating concrete mass will ensure rapid strength gain but in pours such as for the Huntly Power station mass foundations heat can cause thermal differentials. These can crack the concrete either internally or externally depending on when the differential occurs, internally as the concrete is heating up or externally as the concrete cools. The pours at Huntly were 1010m$^3$ of 30 MPa generating heat in the bases of up to 70 degrees.

On the Alpurt B2 Northern Gateway motorway the pile caps for the bridge are 40 MPa and are pours of 100m$^3$. This has required the use of high volume fly ash concrete with the fly ash content in the region of 50% of the cementitious component to reduce peak temperatures.

Certainly concretes property of holding and slowly releasing heat, its thermal mass can be well used in residential and commercial buildings. The thermal mass will regulate the temperature in the building, avoiding overheating while acting like a night store heater through the night. Roger Buck from Christchurch monitored a home to show the internal temperature, barely varying ±1 or 2 degrees, over an 8 day period.

Much of the use of concrete is unseen, the pile caps, the foundations for the Huntly project or the beam under the road. In the sea off New Plymouth concrete mattresses were used to hold down and protect pipes from the gas fields. This required an increased density of concrete to 3 tonne per cubic metre rather than the standard 2.4 tonne. The mattresses consisted of hundreds of concrete filled buckets joined together with ropes to create flexible heavy mats that are taken out to sea by barge and draped over the pipelines.

These are just a fraction of the uses to which concrete can be put. A few examples of how concrete can be varied to suit a particular structure. Bear in mind concrete is just a generic name for a product for which almost every property can vary. A conglomerate of constantly changing nature. Use this flexibility to design and build structures to last, so that future generations are thankful for our sustainable use of resources and the skill of this generation of engineers. The limits are constrained by our imagination alone.

REFERENCES

(1) Concrete Engineering International, October 2000

(2) Highlights in the History of Concrete, Cement & Concrete Association, UK, 1979