Concrete Basics

Concrete’s versatility, durability and economy means it is everywhere, but a successful result requires care and skill no matter what size the project.

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Fresh concrete is a composite mixture of two components: aggregate (usually a carefully proportioned combination of sand and river gravel or crushed stone) and a paste of Portland cement and water.

The water performs two critical functions. First, it allows the fresh concrete to flow, making it easy to mould into a wide variety of architectural forms. Second, it activates a chemical reaction within the cement known as ‘hydration’.

During hydration, individual cement grains begin to sprout fine tendrils that, over hours and days, gradually become entangled with each other and the aggregate, eventually binding all the components of the concrete together (see Figure 1). This process, rather than drying, provides concrete with its strength. In fact, fresh concrete placed under water to set will become stronger than concrete that is allowed to dry out during the hardening process.

An excellent rule of thumb is that the mix should be produced using as little water as possible, but the concrete should be kept as wet as possible after it has been placed and finished.

Reinforcement is important

Hardened concrete has a typical compressive strength of 20–60 MPa, meaning it is resistant to directly applied loads. For example, a slender column of concrete 5 cm in diameter can easily support a mass of more than 4 tonnes! But concrete is only about 1/10 this strong under loads applied in tension – where forces act to pull the concrete apart.

Without including additional tensile reinforcement to withstand bending and shear stresses, most of the concrete construction forms we now take for granted would be impossible. This reinforcement is ordinarily achieved by embedding mild steel rebar within the concrete. Steel is strong in tension, bonds well to the concrete, allowing stress to be shared effectively, and responds to temperature changes in a similar fashion.

Concrete durability

As with all construction materials, there are pluses and minuses (see Table 1).

An advantage of well executed concrete is its long service life without maintenance. Concrete will not rot, corrode or degrade on exposure to normal weathering action. Many structures built in the 1930s and earlier continue to function well (see Figure 2). However, to achieve this longevity, careful attention must be paid to the exposure environment of the concrete, the proportioning of the mix components, their interactions and the techniques used during construction.

Corrosion of the embedded reinforcing steel is the leading cause of premature deterioration in concrete in New Zealand. When steel corrodes, the resulting rust occupies a greater volume than the metal it replaces. This expansion creates tensile stresses in the concrete, which can eventually cause cracking, delamination and spalling (see Figure 3).

Although steel naturally rusts, the alkalinity of concrete (pH of 12–13) ordinarily safeguards it against corrosion. Over time, this protective environment can be lost through the penetration of both salt (from

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**Table 1: Potential advantages and disadvantages of building with concrete.**

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
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<tr>
<td>• Excellent loadbearing capacity in compression.</td>
<td>• Construction of formwork can be expensive and time-consuming.</td>
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<tr>
<td>• Can be cast into almost any shape required.</td>
<td>• Careful quality control and a skilled workforce necessary to achieve good results.</td>
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<td>• Elements can be precast for rapid on-site erection.</td>
<td>• Provides little intrinsic thermal insulation value to buildings.</td>
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<td>• Long service life possible with minimal maintenance costs.</td>
<td>• Concrete buildings are not easily reconfigured.</td>
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<td>• No need for protective coatings.</td>
<td>• Natural appearance can be dour.</td>
</tr>
<tr>
<td>• Fire resistant.</td>
<td>• Cement and steel production are both energy and CO₂ intensive.</td>
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<tr>
<td>• Sufficiently water resistant to be used for water-retaining structures.</td>
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seawater) and atmospheric CO₂. Because this penetration is never entirely preventable, NZS 3101:2006 *Concrete structures standard* specifies the concrete quality and depth over the reinforcement necessary to ensure these contaminants will not reach the steel during the design life of the structure.

A variety of other deterioration mechanisms can affect concrete, for example, distress from repeated freeze-thaw cycles and chemical attack from natural groundwaters with high sulphate concentrations or acidity. Neither are significant issues around most of New Zealand, but the ‘Design for durability’ chapter of NZS 3101 provides appropriate guidelines for using concrete in such severe environments.

**Quality assurance**

A potential disadvantage of concrete construction is its essentially bespoke nature. Careful control of multiple operations, including production of the raw materials, mixing, placing and curing, all ensure optimal results.

Quality assurance is addressed by two standards – NZS 3104:2003 *Specification for concrete production* and NZS 3109:1997 *Concrete construction*. These, in turn, reference specifications for the quality of the cement, aggregates and other concrete mix components and the implementation of testing regimes. Purchasing concrete from a ready-mix supplier who is certified under the NZRMCA Plant Audit Scheme provides independent verification that these standards are complied with.

With a good concrete supply assured, a skilled workforce to place the concrete is the final and most crucial step to achieving a successful result.

**What can go wrong?**

There are some common defects that may compromise finished concrete quality.

**NOT ENOUGH COMPACTION**

Compaction during concrete placement, usually achieved by mechanical vibration, temporarily eliminates the friction between aggregate particles. This allows the concrete to flow into formwork and around reinforcing bars and eliminate trapped air.

Adequate compaction is essential to the strength, durability and appearance of the concrete (see Figure 4).

**INADEQUATE CURING**

Freshly mixed concrete contains much more water than is necessary to hydrate the cement, simply to allow it to flow. However, any appreciable loss of water through evaporation while the concrete is young can delay or halt the hydration, reducing its strength and durability. Taking steps to prevent this, known as ‘curing’, is essential to any non-trivial application.

Covering the concrete with polythene sheets, applying proprietary membrane-forming curing compounds or simply keeping the concrete saturated with water sprinklers for a minimum of 3 days after placing are all effective methods of curing.

**CRACKING**

Unexpected cracking is a frequent cause of dissatisfaction with finished concrete, particularly floor slabs. Restriction of movement due to drying shrinkage is the most common cause. Water that is excess to cement hydration requirements will ultimately evaporate, causing the hardened concrete to decrease in volume. If the concrete is unable to shrink in response, due to restraint from friction, reinforcing or connection to another part of the structure, the strain developed can exceed the tensile strength of the concrete, producing a fracture.

Some drying shrinkage is inevitable. This is usually best managed by the deliberate inclusion of control joints that will ensure the crack is expressed in an aesthetically acceptable manner.

On hot or windy days, preventing rapid loss of moisture from the surface of the newly finished concrete before curing is important to avoid the development of unsightly plastic cracking. This can be achieved by erecting temporary windbreaks and/or sunshades, pouring concrete in the early morning or late afternoon or applying an alcohol-based evaporation retarder following screeding and floating/trowelling operations as needed.

**INCORRECT PLACEMENT OF REINFORCEMENT**

The depth of concrete over the outermost reinforcing steel usually governs the longevity of a concrete structure. Ensuring that the reinforcing is correctly positioned before pouring the concrete is much more cost-effective than repairing the consequences of inadequate cover in later life.

**Free guide available**

Quality concrete work takes care, but guidance for achieving a successful result is easily accessible. The *Guide to concrete construction*, available free of charge on CD-ROM from the Cement and Concrete Association of New Zealand (email admin@ccanz.org.nz), is an excellent place to start.