Multi-storey construction: from research to practice

International research into construction practice can seem a long way from the building site, but the effects filter down surprisingly quickly. The research programmes discussed in this article will have a significant impact on future multi-storey construction in New Zealand – and the impact of some can already be seen.

The concrete industry around the world is investing significantly in research and development to ensure our product can meet the demands for improved quality, greater cost effectiveness and speedier delivery. The following research programmes give a taste of some of the work taking place.

PRESSS

PRESSS (Precast Seismic Structural Systems) research, has focused on establishing ductile or elastic jointed connections that will allow a precast building to behave flexibly in response to displacement (see *concrete* June 2000 and the article page 10). This is a particularly relevant and exciting development for New Zealand, as there is extensive use of precast construction in this country. There don't appear to be, at this stage, any practical barriers to the implementation of PRESSS. The New Zealand Concrete Structures Standard NZS 3101 has been written with sufficient flexibility to accommodate the results of this research.

The system has the potential to speed up construction and almost eliminate the post-earthquake repair cost to structural framework. Its simplicity, using the unique qualities of precast concrete (off site, precision quality manufacturing) to address connection issues, is particularly appealing from a construction perspective. To illustrate, a schematic description of the wall and panel system, which has tested particularly successfully, is given below.

Wall and panel connections

The primary design considerations are the post-tensioning (area and initial stress) and the strength of the energy dissipating connectors. The behaviour of the precast wall during displacement is illustrated in Figure 1: as the wall displaces, each panel rocks about its bottom corner, stretching the post-tensioned (PT) tendon and causing shear displacements in the energy-dissipating connectors that link the panels. If the PT remains elastic up to the design drift, the residual displacement is theoretically zero. Under the maximum credible drift, taken here as 3% at the roof, the tendon must not fracture in order to ensure the survival of occupants. Geometry can be used to satisfy these criteria: to calculate the stress increase caused by the drift and then to select the appropriate initial stress.

The energy dissipating connectors used in the model building were U-shaped Flexural Plates (UFPs), initially developed

Lok-test jack in position

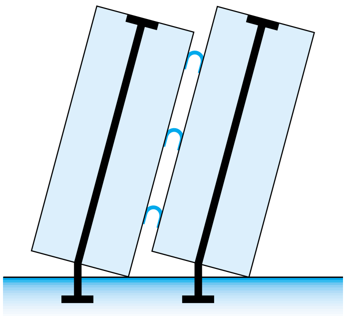


Fig 1: Rocking of precast wall

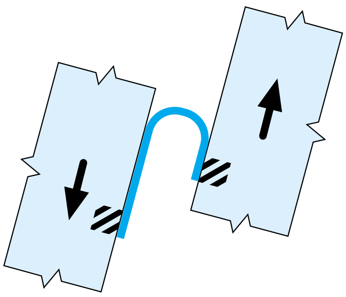


Fig 2: Behaviour of UFP

by Skinner et al [1975] and tested in the PRESSS programme in California by Schultz [1996] They are shown in Figure 2. A flat plate is bent into a U-shape and bolted or welded to plates embedded in the edges of adjacent wall panels. As the wall rocks, the edges of adjacent panels undergo relative shear displacements and force the UFP to roll like a tank track. The curved part straightens and the straight part becomes curved. Plate dimensions and material properties are selected to ensure that yielding occurs and energy is dissipated by the rolling action.

The following conclusions were drawn from the work – indicative, when the guidelines become available, of a real improvement in design and buildability.

1. Precast concrete systems can be designed to resist seismic loading in ways that take advantage of the naturally occurring joints between the precast members.
2. The use of jointed precast systems gives the designer more control over the performance of the building, and in particular the level of damage that will be inflicted during displacement, than is generally possible with cast-in-place systems.
3. The use of unbonded post-tensioning for elastic restoring force, combined with a yielding material to dissipate energy, provides system characteristics that offer considerable promise.
4. Floor connections can be designed to satisfy the force and formation requirements associated with jointed construction.

Cardington

Research into an in situ concrete frame building at Cardington in the United Kingdom aimed to re-engineer the process to reduce costs, increase speed and improve quality. Whilst in situ construction is not as prevalent in New Zealand as in the UK, the results – 30 percent time saving and 45 percent labour savings – mean there is plenty we could learn from this research.

The article given on page 32 shows how improvements and efficiencies can be achieved by rigorous examination of construction processes.

A detailed study of early age (less than three days) concrete acceptance tests was also carried out at Cardington. This is particularly valid for the New Zealand industry, given the current examination of concrete production codes and the potential for greater and earlier confidence in concrete strengths, which would lead to a reduced construction cycle time.

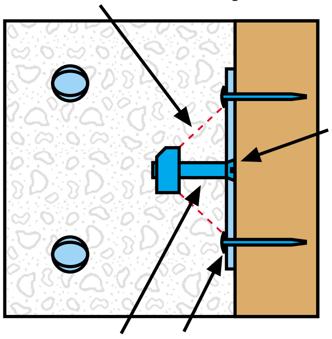
Results have been analysed to enable comparisons in performance of individual test methods: pull out testing, maturity measurements, and temperature matched curing. These have led to recommendations concerning test selection, location and implementation, which will permit long term strength predictions to be made and early age acceptance criteria to be established.

LOK Test

In situ tests such as the Lok test clearly demonstrate a means of verifying that the required strength for early striking (as early as 19 hours after placing the final concrete in a slab) has been achieved.

It has not been used in New Zealand yet, but given the work done at Cardington, knowledge of concrete strength at an early age will advance performance here.

The Lok test measures the tensile force required to 'pull out' a metal insert that has been cast into concrete. Load is applied through a manually operated jack, which bears against the concrete



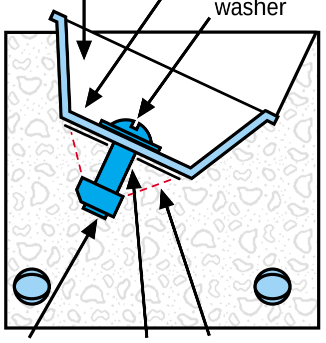


Fig 3:
Lok-test inserts

surface through a reaction ring of 55 mm internal diameter. There are two main types of insert: the first attached directly to the formwork and the second fixed to a plastic buoyancy cup, which 'floats' on the top surface of the concrete, for use on slabs. Both types of insert can be seen in Figure 3.

Key messages from the Lok test research
Knowledge of concrete strength at an early age:

- allows significantly increased efficiency of in situ concrete frame construction;
- enables early striking of formwork and its economic re-use. This is further explained in Cardington publication Best Practice Guide, Early striking for efficient flat slab construction;
- enables early prestressing with safety;
- can give an indication of long-term strength, enabling early confirmation of the quality of the concrete as placed.

Lightweight concrete

Research on the seismic performance of lightweight concrete at the University of Canterbury was extended to examine the confinement steel in column reinforcing, following tests that indicate current methods are over-estimating the required steel. If these tests are proven to be correct, the days of congested column stirrups may be numbered – with a resulting impact on the speed and cost of columned construction.

Local practice

The local industry is already responding to the demand for new improved methods and processes.

Modular construction

While not new to the New Zealand market, glass reinforced panels (GRC), which offer time and cost savings when used as modular elements, have not been widely used. This is now changing. Hartner Construction had windows for their recent Wellington apartment building installed into GRC panels at the precaster's yard making on-site construction faster and more cost effective. (See case study page 22)

Standardisation at Precast New Zealand
Precast New Zealand has been thinking about how its industry can re-engineer processes to simplify and speed up building, and deliver cost savings. Precast NZ is taking a similar systemic approach to the Cardington research team, considering optimisation, standardisation of elements and better integration of processes to save time and cost.

The first draft of the Precast NZ Code of Practice for the preparation of shop drawings is out now, and will be followed by other similar initiatives.

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