

# Innovative Residential Flooring Solution for the TC3 Foundation Category

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**ABSTRACT:** The TC3 foundation category in Christchurch represents the most challenging category in which to design cost effective residential foundation systems. The paper describes an innovative solution designed to meet the challenges of providing a concrete floor foundation system which allows garages to be an integral part of the home.

The paper not only presents the developed solution but also the unique NZ approach to collaboratively developing a solution. Consultation with the EAG, PMO's, BCA, geotech/structural designers, and contractors were required to formulate a solution which meets both technical and commercial objectives.

The solution is a concrete surface foundation system which incorporates an embedded jacking system. Jack capacities have been independently verified and tested in a prototype foundation. The prototype has been lifted numerous times demonstrating the re-levelability of the system. It is estimated that, if required, a house could be relevelled in a matter of hours. The system is suitable for single storied dwellings within the minor to moderate SLS vertical settlement and up to major lateral stretch. Options are being explored to develop a modified jacking system which would allow the system to be extended to small commercial and two storied structures.

## 1 BACKGROUND

### 1.1 Technical Foundation Category TC3

Following the Canterbury Earthquake sequence, the Department of Building and Housing, DBH, (now the Ministry of Business, Innovation and Employment MBIE) have subdivided the green zone of Christchurch into three categories for foundation (TC1, TC2, TC3). The TC1 category is reserved for land where land damage from liquefaction is unlikely. In TC1 conventional NZS3604 foundations can be used. TC2 is reserved for areas where minor to moderate land damage from liquefaction is possible in future earthquakes, while in TC3 areas moderate to significant damage is expected. Figure 1 illustrates the location of the technical categories for the majority of Christchurch. The TC3 areas being shaded in blue.

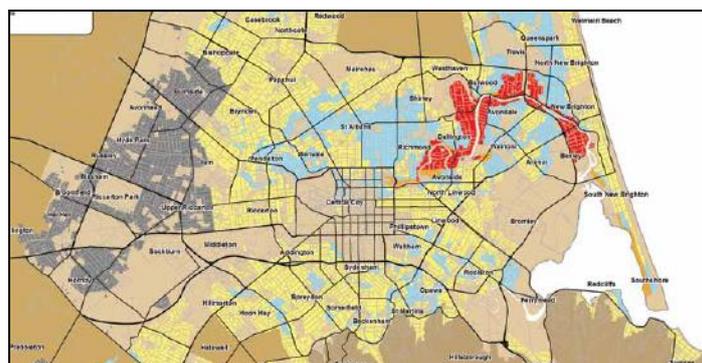


Figure 1 TC3 foundation categories shown in blue for central Christchurch (from reference 1)

The categorisation of the foundation Technical Categories is predominantly based on the expected land settlement from liquefaction. Table 1 illustrates the expected land performance for the three foundation categories. In TC3 settlements of greater than 50mm are expected in a SLS seismic event and over 100mm in an ULS event. Therefore foundations in the TC3 category need to be able to accommodate significant potential settlement.

Table 1 Categorisation of foundation zones (from reference 1)

FOUNDATION TECHNICAL CATEGORY	FUTURE LAND PERFORMANCE EXPECTATION FROM LIQUEFACTION	EXPECTED SLS LAND SETTLEMENT*	EXPECTED ULS LAND SETTLEMENT*
TC1	Negligible land deformations expected in a future small to medium sized earthquake, and up to minor land deformations in a future moderate to large earthquake.	0-15 mm	0-25 mm
TC2	Minor land deformations possible in a future small to medium sized earthquake, and up to moderate land deformations in a future moderate to large earthquake.	0-50 mm	0-100 mm
TC3	Moderate land deformations possible in a future small to medium sized earthquake, and significant land deformations in a future moderate to large earthquake.	>50 mm	>100 mm
Un-categorised	Land in the un-categorised area will contain properties that experience future land performance as per one of the above categories. It also includes urban non-residential land, unmapped rural land, the Port Hills and Banks Peninsula. A geotechnical engineer should be engaged to determine the appropriate solution for the property, based on a site-specific investigation.	N/A	N/A

In April 2012 the DBH published the report “Interim Guidance for Repairing and Rebuilding Foundations in Technical Category 3”. This document provided guidance on 3 broad categories of acceptable foundation solutions, these being-

- Foundations on deep piles.
- Foundations on ground subject to site improvement.
- Surface shallow foundations.

Each of the above solutions have their merits and limitations. However the shallow surface solutions generally have the advantages of being less costly and perceived to be less likely of cost escalation once construction commences.

The April 2012 DBH guideline provided 3 foundation types for surface structure foundations option. The methodology adopted was essentially to provide “acceptable solutions”. Details of each solution were presented and limitations on their use summarised. However missing from the guideline was an explanation of the underlying philosophy used to develop the acceptable solutions. This meant that designers were limited in their ability to demonstrate equivalence for any alternative solution.

## 1.2 Why develop a solution outside of the MBIE guideline

The shallow surface solutions presented in the April DBH guide all incorporated timber floors. This created several difficulties within the market. Homeowners who had become accustomed to homes with concrete floors were often reluctant to accept a timber floor solution requesting from their insurers that they receive like for like. Also attached garages are considered the norm for modern homes, a detached garage being considered an inferior offering. Homeowners want and expect a concrete floor in their garage. Combining a timber and concrete floor at a similar elevation in a TC3 foundation category is a considerable design challenge and outside the scope of the DBH guide.

Firth Industries embarked upon a research and development project with the aim of producing a concrete residential solution for the TC3 zone. The aim was to resolve market demands for a concrete floor solution and to provide a viable economic solution for what had become a very slow moving segment of the Christchurch rebuild.

## **2 PERFORMANCE REQUIREMENTS FOR TC3 FOUNDATIONS**

### **2.1 Performance requirements for a Relevelable solution**

To develop a solution with at least equivalent performance to the shallow surface structures documented in the DHB guideline required resolving the target performance requirements for such a structure. After many meetings and considerable communication (refer next section) it was resolved that the requirements and performance expectations for TC3 specifically designed concrete foundations are as follows:

1. The application of such systems is limited to sites where less than 100 mm SLS settlement is expected.
2. A geotechnical engineer should assess deep geotechnical information (either site specific or area wide information) as per the current requirements for surface structures in section C5.4.7 of Appendix C (as amended).
3. The finished floor level is to be a minimum of 300 mm above adjacent ground or on sloping sites a minimum of 250 mm and an average of 300 mm above adjacent ground. Note that flood level requirements may result in greater heights above adjacent ground. NZS 3604 clearances above adjacent ground and E1/AS1 clearances must also be complied with.
4. Foundations to support an NZS 3604 superstructure with lightweight roof claddings and limited to light or medium weight wall claddings.
5. Re-leveling can be carried out with non-specialist equipment, techniques or materials.

Key performance expectations:

1. A stiff foundation plate that can span between any temporary point load supports during the re-leveling process. This will typically involve the use of an underslab to jack against during re-leveling.
2. Floor plate curvatures under differential ground settlement in the load condition of  $G + 0.3Q$  should be less than 1 in 400 (ie, 5 mm hog or sag at the centre of a 4 m length) for the case of no support over 4 m, and no more than 1 in 200 for the case of no support of a 2 m cantilever at the extremes of the floor.
3. Foundation is readily re-levelable – can be lifted after any settlement event and again in subsequent events.
4. The re-leveling and repair (including any associated superstructure damage) can be completed within a 4 week period during which the occupants may have to be relocated.
5. No damage to services within the floor plate in SLS events and readily repairable at the outside of the foundation following the earthquake and during the re-leveling process.
6. Any system should have sufficient seismic lateral resistance at ULS.

### **2.2 The NZ way of solving problems- co-operation**

Relatively unique to NZ is the collaborative way we tend to work. The work load of many engineers and advisors after the Christchurch earthquake sequence was immense, and yet time was found to address issues and provide better solutions for the rebuild of Christchurch. There would be few places in the world where officials from both National and Local Government would enthusiastically work with structural engineers, geotechnical engineers, building practitioners, project managers, and material suppliers to create an environment where innovative, complying solutions, have an opportunity to be developed.

To develop the guiding principles provided in the previous section required considerable dialogue and the input of numerous specialists.

## **3 THE DEVELOPED SOLUTION**

### **3.1 Description of final solution**

Product development is often an iterative process slowly moving towards the optimal solution. The

epitome of good design is often a solution which appears very simple, is easily understood and robust. However to obtain a building consent will require all aspects of the building code to be considered and appropriately addressed.

Firth has for many years provided a flooring solution called RibRaft. This product is a TC1 foundation system and is the only residential solution with a CodeMark tick of conformity. The decision was made to develop a TC3 solution based on the RibRaft technology as many of the non structural building code compliance requirements had already been addressed.

The final TC3 solution comprises of-

- A Jacking slab designed to provide a flat bottom to the flooring system, provide flexural stiffness during a liquefaction event, and support the point loads from jack if the floor is ever required to be relevelled.
- A modified RibRaft which is separated from the jacking slab via a polythene layer. The RibRaft incorporates a patented encased jacking system.
- A fibre reinforced concrete mix with assessed and documented performance characteristics.
- A procedure for releveling the slab which can be conducted using non specialist staff.

The system is best illustrated though the following annotated photographs.

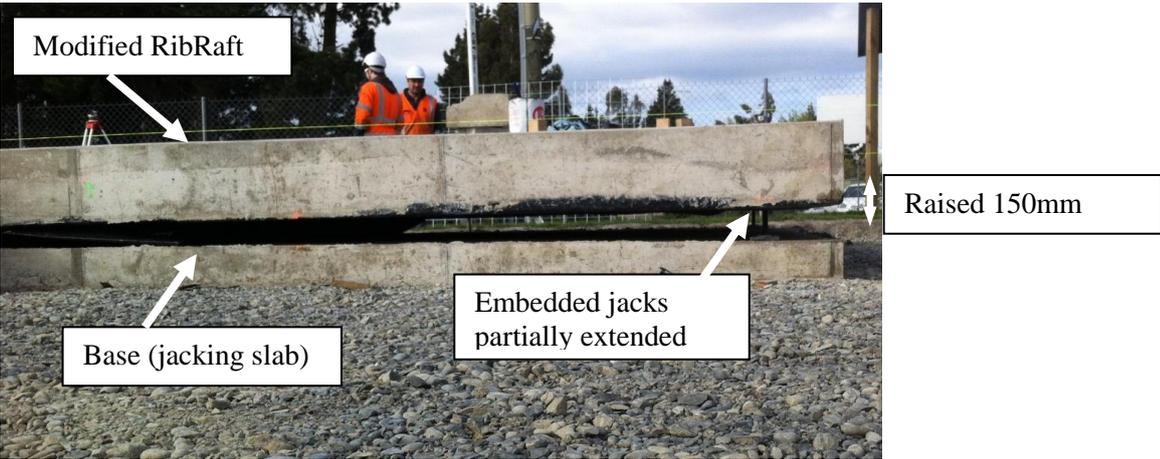


Figure 2 Relevelable residential concrete floor solution showing components



Figure 3 internal jacks prior to pouring concrete



Figure 4 blocks to mimic weight of building cladding, plus rattle gun used to raise slab.

### 3.2 Limitations of system

The flooring system does have some limitations on its use. The jacks have capacity restrictions which mean that light weight cladding and roofing is required. However this is a requirement for all TC3 foundation solutions with the exception of piled solutions. The system is also only suitable in zones where the ground surface settlement in an SLS is estimated to be less than 100mm. It can be used in minor to major lateral spread zones. Experience with standard RibRafts in the red zone have shown that the flat underside of this foundation system plus the use of reinforcement provides a good degree of protection against splitting the slab when lateral spread occurs. Figure 5 illustrates the geotechnical conditions in which the TC3 foundation system can be used.

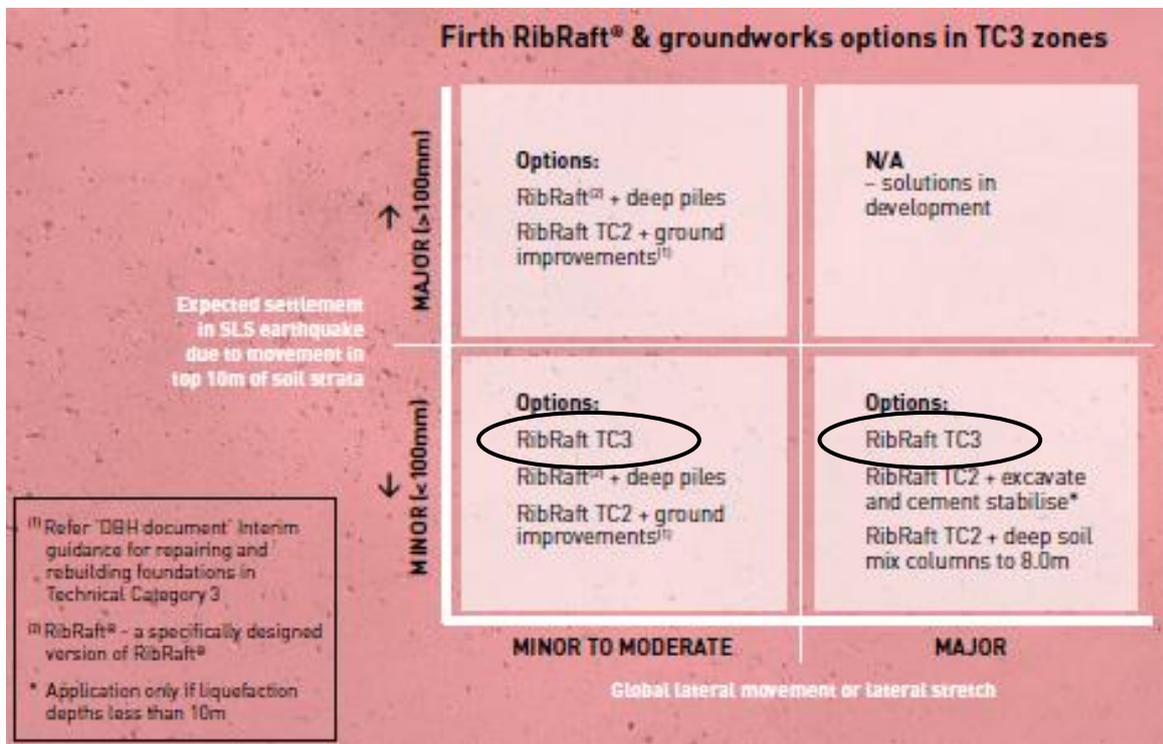


Figure 5 matrix showing geotechnical conditions in which the releveable slab can be utilised.

### **3.3 The Building Consent process**

In December 2012 the first of these floors was given a building consent. The design and documentation was conducted by EngCo, while supporting technical information was supplied by Firth Industries. The process was quick and efficient mainly due to the numerous meetings in the development of the system to ensure that all performance requirements were achieved. Building a prototype floors was extremely valuable in allowing all to understand the system.

## **4 THE DEVELOPMENT PROCESS**

### **4.1 Proof of concept testing and development of product collateral**

The system in its entirety was tested by the construction of a full sized prototype slab at Firths Offices in Broughs Road Christchurch. This allowed the constructability of the systems to be examined and tested the system in its entirety. Several small improvements to the jacking system were made as a result of this testing. The improvements focused on providing the ability to accommodate normal construction tolerances and ensuring the jacks were sufficiently robust to accommodate normal construction abuse.

The test slab confirmed the performance of the solution; however individual components were also tested. Holmes Solutions conducted tests on the jacking system determining the capacity of the system when combined with standard rattle guns. The testing explored the capability of the system when it is well greased and also when the bolt system is dirty.

International test data was utilised to develop the capacity of the fibre reinforced base slab.

To assist potential designers of the system a design guide has been produced. This design guide identifies-

- Design load cases to be considered.
- Capacities of the components of the upper RibRaft.
- Capacities of the jacking slab when jack loads are applied in different location of the slab.
- Capacities of the jacking system
- Guidance on geotechnical conditions for which the system is appropriate.

Also provided in the system collateral is documentation on the process to be adopted if the system was ever required to be relevelled.

### **4.2 Working towards a common goal**

The success of the system has in large been due to the fact that all involved had the common goal of providing a solution which satisfies many of the needs of those in the TC3 foundation category who require foundation rebuilding. The input from insurance project managers (in particularly Arrow International), the engineering Advisory Group (both geotechnical and structural) and contractors familiar with RibRaft construction have all assisted in focusing and fine tuning the system.

## **5 CONSTRUCTION AND QUALITY CONTROL**

### **5.1 Accredited installers**

With the aim of improving the quality of residential construction, the decision has been made to limit the construction of the system to accredited installers. Installers who are familiar with the existing RibRaft system are being provided training and accrediting to ensure that those installing the system do so to the full extent of the construction specification. The first installed floor was constructed in February 2013 by Reliable Foundation Limited.

## 5.2 Competency assessment

Firth has on its staff BCITO trained competency assessors. These assessors are normally responsible for the training and assessment of Firths ready mixed concrete, masonry and Dricon staff. Many of the key quality control activities such as batching and testing are controlled by the need for an annually renewed licence. The trained assessors will be used to conduct random audits of installers to ensure that competency is evident.

## 6 CONCLUSIONS

A viable cost effective concrete foundation system is available for the TC3 foundation category. The system was developed with a unique NZ approach of multiple organisational co-operation. The system has been tested by the construction of a full sized prototype and was found to be a robust and easily constructed system.

## 7 REFERENCES, SYMBOLS AND UNITS

Department of Building and Housing 2011. Revised guidance on repairing and rebuilding houses affected by the Canterbury earthquake sequence. *Department of Building and Housing, November 2011*, Wellington

Department of Building and Housing 2012. Interim guidance for repairing and rebuilding foundations in technical category 3. *Department of Building and Housing, April 2012*, Wellington