

Strengthening of St Mary of the Angels Parish: Lessons in Temporary Works Engineering

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2017 NZSEE
Conference

ABSTRACT: Earthquake strengthening a heritage building can be a complex and difficult undertaking. In a Gothic styled church like St Mary of the Angels the architecture and structure are so closely intertwined that safely opening any work front requires a carefully planned and sequenced approach. Significant engineer designed temporary works were required to complete the seismic strengthening regime which included new ground beams adjacent existing shallow foundations, four large concrete shear walls inserted within the nave, replacing existing concrete columns and portals in-situ, structural bracing to steep roof planes, and new foundations to the large bell towers. These complex work fronts were completed while ensuring that the seismic performance of the structure was not lessened throughout the works. This required the contractor and temporary works engineer to work collaboratively in designing and executing a wide array of unique and traditional temporary works solutions.

The aim of this paper is to provide a fresh perspective of the skills and knowledge repertoire required from a temporary works designer to aid the contractor in the safe and successful delivery of significant heritage structures. The paper will first discuss the necessary attributes of a temporary works designer from a contractor's perspective, before discussing the key engineering principles to consider in complex temporary works designs. A number of examples from the strengthening of St Mary of the Angels will be used to illustrate both perspectives.

1 INTRODUCTION

St Mary's seismic improvement project is a complex and extensive strengthening project in the CBD of Wellington. Originally constructed in 1922 of semi reinforced concrete the seismic improvement works design by structural engineers Clendon Burns and Park Ltd required the installation of not only new reinforced concrete and structural steel elements but also required the removal and replacement of many existing primary structural members, see Figure 1 for general view. It was very early on recognised by LT McGuinness Ltd (LTM), the main building contractors, that the key to this projects success was in the efficient use of temporary works. Dunning Thornton Consultants Ltd (DTC) who have a long history of temporary works design for LTM were engaged early in the project to help work through the solutions. Reflecting on the experiences during this project has led to this contractors and temporary works Engineers perspective on the temporary works design process.



Figure 1: Church Photo – View looking westwards

2 TEMPORARY DESIGN - A CONTRACTOR'S PERSPECTIVE

This section outlines the required character attributes and design considerations of a proficient temporary works designer from a contractor's perspective. Interviews were conducted with three senior construction managers who were involved at various stages of the St Mary of the Angels strengthening project.

The following character attributes were highlighted. Firstly, it is important the designer demonstrates a willingness to listen to the contractor to clearly understand their needs. Asking the contractor to sketch up their vision is a helpful way to begin the process. Secondly, they need to be effective and clear communicators. They should be happy to roll their sleeves up and engage the various trades onsite, and ideas should be communicated via simple sketches. Thirdly, proficient Engineers are practical thinkers with good construction experience. Fourthly, innovation is important as out of the box designs are often required.

In order for temporary works to achieve their intended purpose designers should factor the following design considerations:

A) Understand the contractor's key objectives/vision at the outset. What are they trying to achieve?

What work fronts are they trying to open up? How are they intending to setup, use and relocate the temporary works? What are the site operations or access requirements surrounding this work?

Strengthening St Mary of the Angels required the concrete portals to be propped while new ground beams, columns and portal knees were replaced in situ. The contractor's vision involved a mobile temporary structure that would act as a propping frame, provide access to multiple work fronts, act as a safe zone within the building, and avoid impeding on a number of structural elements within the church. Once the contractor's vision was understood detailed designs could be produced.

B) Understand the main design parameters and constraints of the site. It is critical for the designer to understand the construction process, appreciating that problems need approaching to the fourth dimension as projects like St Marys involve a complex sequence of events to unlock various work fronts. Asking the following questions can be helpful: What adjacent structural elements can we utilise and what do we need to keep clear of? What time durations are involved with the work? What elements will be completed before, during and after this temporary work is in place?

C) Produce an economic solution for the design. Pricing temporary works at tender stage is often an inexact science, typically with a number of provisional sums allowed, therefore ask the following questions: What financial allowances have been made for the work? What equipment and plant does the contractor have available that could be utilised? Can the design be simplified? Can the works be

prefabricated offsite and lifted into place? Does the design allow for simple erection, easy relocation and possible reuse? Can permanent structural members such as steel columns be procured early and utilised in temporary works designs? Can permanent structural elements be adjusted to serve a temporary works purpose?

D) Utilise the contractor's preferred construction methodology; The tried and tested. What systems does the contractor have experience with? What are their preferred fixing/fastening methods? Giving the contractors an opportunity to critique the design, or input their preferred methods will help to increase productivity onsite.

3 TEMPORARY DESIGN – AN ENGINEER'S PERSPECTIVE

Temporary works design requires the engineer to design systems to support the vertical and lateral loads of the construction works at the different stages of the construction programme. Generally the loads are as prescribed in AS/NZS1170 but sometimes as in the case of Saint Mary's special criteria apply. For Saint Mary's building insurers required the seismic capacity of the building to be no less during the construction works than before.

It is important that the temporary works engineer recognise that their client is the Contractor and they must strive to fulfil the Contractor's requirements. In particular, they should thoroughly understand programme, material and Health and Safety constraints. They should be very familiar with construction methods, scaffolding and propping proprietary systems. They should have good communication skills and have good sketching skills. It is highly recommended that the design temporary works engineer is briefed at a face to face meeting with the Contractor, visits the site before designing structure and visits site after the temporary works are constructed. It is very likely any design engineer undertaking temporary works will have CPEng (Structural) qualification. The importance of a site visit after the temporary works are constructed by the design engineer cannot be stressed enough. Often during the temporary works construction the temporary structure is changed due to practical on site requirements. Sometimes these changes are not conveyed directly to the design engineer leading to the potential for structural deficiencies.

4 ST MARY OF THE ANGELS – TEMPORARY WORKS EXAMPLES

Saint Mary's seismic improvements required a wide array of unique and traditional temporary works solutions. The following specific examples demonstrate how close cooperation between Contractor and Engineer lead to successful outcomes for the Contractor. They also demonstrate key principles of temporary works design.

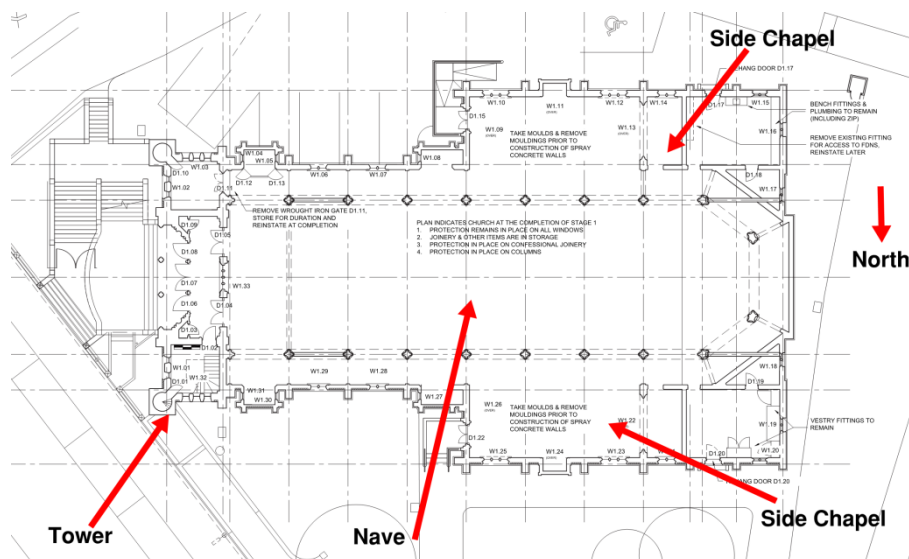


Figure 2: Key Plan

4.1 Gantry

Early in the construction planning phase LTM realised the need for an innovative solution to support the existing concrete portal frames. The existing concrete portal frames were to be demolished and replaced with new reinforced concrete portal frames except for the top 4m long sections which were to remain. A system was required to support the existing concrete and the timber roof between portal frames and to maintain the lateral load resisting capacity temporarily removed due to the portal demolition.

LTM realised traditional propping systems would occupy significant space in the existing nave, be slow to erect and disassemble and be costly. A moveable propping frame, working platform, access system was required. Hence the gantry frame.

The gantry was conceived as an A frame propping system mounted on a bespoke gantry rail system, see Figure 3. The steelwork was required to be relatively light weight for ease of erection and disassembly. Two levels of working platform were required and a jacking frame to support the concrete portal beams. Jacking between the steel work and the existing concrete was seen to be critical to ensure load transfer was achieved prior to portal demolition. During the jacking process displacements of the steel beams supporting the concrete frames were monitored by the contractor and temporary works designer.

The lateral stability in the transverse direction was achieved using the A frame configuration and in the longitudinal direction by diagonal tension bracing. At each set up location the gantry chassis was directly tied down to the UB rails for global stability purposes.



Figure 3: Gantry during erection

The gantry proved to be an excellent means of achieving LTM's objectives. It was an efficient means of propping, proved to be versatile for the mounting of access and platform scaffolding systems and could be relocated relatively easily. Later in the construction process it was altered relative easily for reuse as a plastering and painting platform. It is also suitable for reuse on other projects.

4.2 K Frames to Nave Arches

The demolition and replacement of the existing concrete portal columns to the nave required the propping and support of the existing concrete work between the demolished columns. The existing concrete work not only needed support but also the temporary provision of longitudinal bracing to the nave to ensure the seismic strength of the building was no worse during the strengthening than before works commenced was required. Once again it was realised a jacking procedure would be required to

ensure appropriate load transfer. The system would be reused many times and therefore had to be simple and robust. The K frame system was conceived to meet these challenges, see Figure 4. Although not constructed from proprietary shoring products its efficiency and economy lies in its repeated use on the site and its robustness.



Figure 4: A pair of K brace frames with column between removed

In a couple of instances modifications were made to the frames to allow intermediate columns to be removed between propped bays to increase speed of construction on site.

4.3 A Frames to Side Chapels

As work progressed towards the western end of the church it became evident that the existing steel ties between portal knees would need to be removed prior to the relocation of the gantry frame to these locations. This was considered to be structurally unacceptable without providing a means of preventing spreading of the portal knees.



Figure 5: A Frame to Side Chapel

The A Frame raking propping frames to the side chapels were conceived as a means of providing the horizontal reaction at the portal knees and as a means of temporary support to the side chapel concrete rafters, see Figure 5. Jacking between the main concrete portal knee and the supported side chapel concrete rafter ensured load transfer. The form of the A frame prop was tailored to suit the access constraints into the site. The A frame also provided lateral stability to the side chapel during the works.

The A frame proved to be an efficient propping mechanism and allowed the construction works to proceed within programme constraints.

4.4 Roof Platform and Lifting Frame

The extremely steep angle of the existing roof structure immediately concerned LTMs for Health and Safety and construction programme reasons. Working at height on such a steep gradient was considered impractical. A simple, reusable and safe access and working platform was required. It needed to be flexible and easily located up the gradient of the roof.

LTMs conceived the idea of a wheel mounted platform on winches with suitable safety mechanisms, see Figure 6. The structure of the roof platform involved the use of standard aluminium scaffold trusses with scaffold tube restraints, safety rails etc. During use the platform was securely fixed to the substructure with locking pins so that reliance on a mechanical winch was not required.

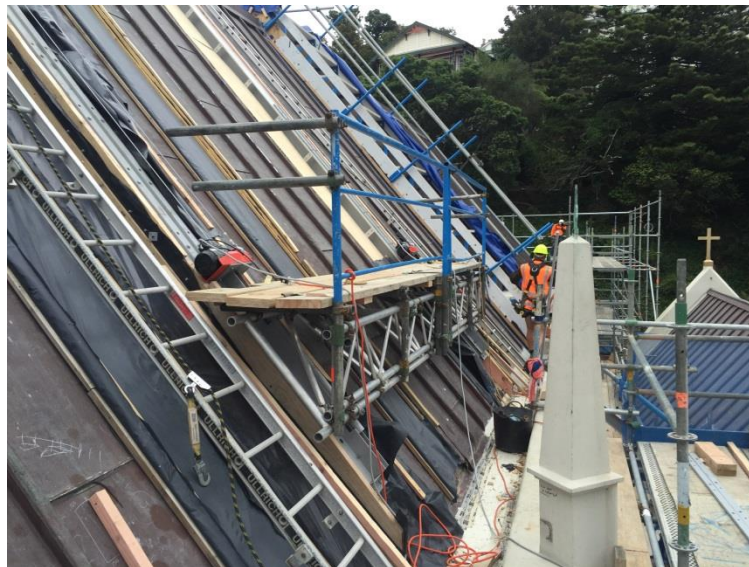


Figure 6: Roof Platform

The platform was efficient, economic and reusable. It significantly improved health and safety outcomes on site and increased productivity on site.

Fabrication of as much roof framing on the ground rather than on the roof was also considered to be an appropriate health and safety strategy. A lifting frame constructed of simple bracketry using the new roof members as the structural components was also devised. This increased productivity and reduced a significant working at heights hazard.

4.5 Altar Lifting Platform

The existing white Italian marble stone altar was required to be relocated out of the work site. The altar stonework is not mortared together and has no mechanical fixings. If the altar was to be lifted a means of maintaining a compression force across all stone joints needed to be devised.



Figure 7: Altar Rail

The altar lifting frame was conceived to achieve this, see Figure 7. Continuously threaded reinforcing bar in tension maintained a compression force on the stonework during lifting. The simple lifting frame allowed a simple relocation operation to move the altar with no damage. The frame was simple to fabricate and achieved heritage requirement of no damage (i.e. fixings).

4.6 Tower Underpinning

The existing concrete bell towers were required to be refounded on an highly weathered greywacke rock approximately 2.5m below their original founding level. As per the requirements of the church the towers were required to have no lesser seismic stability during the works than before construction began. The final design for the towers utilised a rocking foundation mechanism with dampers installed between newly formed foundations. The tower walls were to be sawcut to achieve the rocking mechanism but for construction practicality the sawcuts had to be made before the installation of the new foundations.

The underpinning required careful planning of the underpinning sequence to ensure stability of the towers. A Registered Surveyor monitored the towers for settlement and rotation of the towers during the works.

To maintain the lateral stability of each tower the ground anchors provided for in the final strengthened configuration were extended further up the tower to a ring beam above foundation level to provide the hold down forces for the tower during construction. Close cooperation between the temporary works engineer, the seismic strengthening design engineer and the contractor was required. Small alterations were made by the seismic strengthening design engineer to facilitate the design of the temporary works.

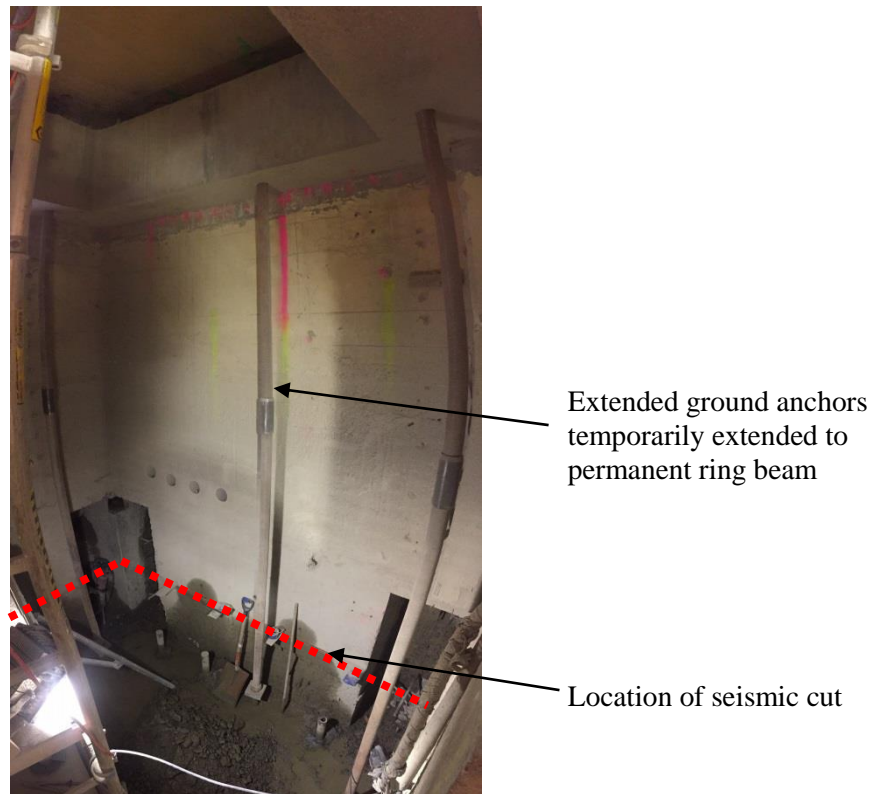


Figure 8: Tower Ring Beam

5 CONCLUSION

Temporary works engineering is typically a challenging task. In this paper the experiences of LT McGuinness building contractors and Dunning Thornton Consultants, temporary works structural engineers have been shared using the very successful construction works at St Marys of the Angels as an example. Close cooperation and communication are seen to be key but also the temporary works engineer needs to have some key attributes to ensure the temporary works meets the Contractors construction goals.

6 ACKNOWLEDGEMENTS

The authors would like to acknowledge the support of the staff of both LTM and DTC in producing this paper and in completing the temporary works at St Mary's of the Angels. Kerrin Manuel, Brian, Peter, Sean and Chris McGuinness from LTM. Steve Butterfield of Burnsfield Engineering. They also acknowledge the close cooperation of Anthony Taylor of Clendon Burns and Park Ltd in providing expert guidance on the permanent works engineering issues throughout the temporary works. Of course this successful and complex project could have not have been completed without a supportive Client, Father Barry Scannell, parish priest of Saint Mary of the Angels.