REPORT ON FACILITATED DISCUSSIONS WITH ENGINEERS FOR CHURCH PROPERTY TRUSTEES AND THE GREAT CHRISTCHURCH BUILDINGS TRUST ON ENGINEERING OPTIONS FOR REPAIR, RESTORATION OR REPLACEMENT OF CHRISTCHURCH CATHEDRAL

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INTRODUCTION

ChristChurch Cathedral is arguably the city's most identifiable landmark and a building of considerable heritage and architectural value. It is the oldest Anglican cathedral in the country, the only building by Sir George Gilbert Scott in New Zealand and the only cathedral he designed in Australasia. It is registered as a "category one" site by the New Zealand Historic Places Trust – Pouhere Taonga and as "group one" site by Christchurch City Council. These heritage listings are the highest available to either organisation. The cathedral has served as the mother church of the Anglican Diocese of Christchurch for more than 130 years and is a place of profound significance to the Anglicans of the city and province.

Five years after the earthquake of February 2011, the cathedral remains significantly damaged. Protracted litigation between Church Property Trustees – as owner – and the Great Christchurch Buildings Trust – a charitable trust established to preserve Christchurch's historic buildings – has delayed a decision on the cathedral's future.

Concerned that the delay was holding back the city's regeneration, the Government – with the parties' agreement – recently appointed me to facilitate discussions between both parties' engineers on the cathedral's condition and engineering options for its "repair, restoration or replacement". The terms of engagement (Appendix 1) require the engineers to address three particular issues:

- the level of damage and risk with the present structure
- what is required to mitigate any risk and ensure safe access to investigate repair, restoration or replacement options
- whether the cathedral can be repaired or restored, in whole or in part, to 100 per cent of new building code standards.

The Government requires any option for repair or restoration to meet appropriate safety standards. It also requires indications of the cost of any options.

As the terms of engagement require, the parties' engineers were not asked to recommend any option, and have not done so. It will be for Government, and the parties, to consider the report and determine the next steps. Those next steps will require consideration of a range of non-engineering matters.

The facilitation process

The litigation between the parties concerned complex trust and insurance issues, although it was triggered by Church Property Trustees' decision to deconstruct the cathedral to sill level in response to a notice under section 38 of the Canterbury Earthquake Recovery Act 2011. (In making that decision, Church Property Trustees took into account various matters, including engineering, safety, liturgical and cost factors.)[1] The litigation did not address engineering issues.

The facilitation process has given the parties' engineers an opportunity to consider – and try to agree on – engineering options to repair, restore or replace the cathedral to a safe standard, free of legal, commercial or other non-engineering-related considerations. I have met the parties' lead engineers on a number of occasions, independently of the parties.[2] The lead engineers were John Hare of Holmes Consulting Group (for Church Property Trustees)

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[1] See issue one.

[2] I did, however, meet with the parties separately to ensure their confidence in the process, and also with their lawyers to agree on procedural aspects relating to the facilitated discussions and to secure their co-operation with the process.

and Adam Thornton of Dunning Thornton Consultants (for the Great Christchurch Buildings Trust). Both discussed engineering options in a constructive manner with a particular focus on the option to repair and restore as required by the terms of engagement (issue three above).

Quantity surveyors David Doherr of Barnes Beagley Doherr and Julian Mace of Rawlinsons also participated constructively in the process to provide indicative costs of the available options. All discussions were conducted without prejudice and confidentially.

I am pleased to advise that the engineers and quantity surveyors have reached a large measure of consensus on engineering options and indicative costs, although the consensus is necessarily high level. Such differences as exist between the engineers are mainly methods of implementation. The engineers agree that it is feasible, from an engineering perspective, to "reinstate" the cathedral (through a combination of repair, restoration, reconstruction and seismic strengthening) or to replace it entirely.[3]

Should an early decision be taken to reinstate the cathedral, a completion date of the end of 2022 is possible. Approval of a fast-tracked design, approval and construction process could bring forward that date by 12 to 18 months. Indicative costs are $105 million.[4]

Should the decision be to replace the cathedral, a completion date of the end of 2019 is forecast, although this date will inevitably be influenced by the nature of any replacement cathedral and the time taken to retrieve artefacts from the cathedral. Indicative costs for a cathedral of a similar size and scale (based on one particular design) are $63 to $66 million.

Both of these deadlines anticipate early agreement on funding and other key considerations, and, importantly, an absence of litigation over resource management, heritage or other issues. Should litigation ensue, a realistic completion date for reinstatement or replacement may be many years away. Litigation over the replacement option is a real prospect.

It must be emphasised that the consensus embodied in the report represents the professional views of the contributing experts, rather than those of their clients. However, the fact the experts have reached substantial agreement clarifies the options for the Government and parties and offers a basis to determine the cathedral's future.

Finally, I acknowledge the assistance of Peter Gunn of Crown Law and the excellent co-operation of not only the engineers and quantity surveyors but also the parties and their lawyers in this process.

What now follows is the agreed outcome of the facilitated discussions. The report is divided into five sections:

* summary of engineers' conclusions
* engineering options: some preliminary comments
* issue one: level of damage and risk
* issue two: mitigation of risks and steps to ensure worker safety
* issue three: whether the cathedral can be repaired or restored

Miriam R Dean

Miriam R Dean CNZM QC
Facilitator

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[3] For definitions of these various terms see page 7.

[4] All indicative costs exclude GST.

SUMMARY OF ENGINEERS' CONCLUSIONS

General

- The options outlined in the report are necessarily general because of the nature of the engineering design process and because engineering and design work already completed is sufficient for estimation and planning purposes.
- Replacing the cathedral presents no particular challenges from an engineering perspective.
- A replacement cathedral could be totally new or could include adaptation of parts of the existing building.
- To repair only or to restore only are not viable engineering options because they would not bring the cathedral either in part or in whole up to 100 per cent of the seismic requirements of the new building code.
- What would be required is a combination of repair, restoration, reconstruction and seismic strengthening, an approach defined for this report as reinstatement.
- The cathedral can be largely reinstated to the extent that, for most people, it would be indistinguishable from the pre-earthquake building.

Damage

- Damage to the cathedral is such that it is unsafe for use until reinstated or replaced.
- Portions of the tower and west wall have collapsed or have been substantially demolished. Other parts are damaged to varying degrees. The worst damage is concentrated in the walls between the eaves and sills, which typically consists of lines of cracking, the crack widths varying from a few millimetres to about 60 millimetres.

Mitigating risks

- A decision on the building's future can be made on the basis of what is already known. No further access is needed to enable on-site investigation of options. Once that decision is made, however, mitigating risks to workers will be critical.
- Reinstatement would require temporary stabilisation, both as a prelude to permanent strengthening, repair and restoration work and also to provide appropriate worker safety.
- The engineers agree on the conceptual form of this temporary stabilisation, but not on the precise method of its implementation. This disagreement is immaterial to the report's outcome.
- Temporary stabilisation of a similar form is in use at the city's Arts Centre and is also being used in the seismic strengthening of Wellington's St Mary of the Angels.
- Temporary stabilisation for reinstatement purposes would cost about $9.65 million.
- Replacing the cathedral would require some limited temporary stabilisation so artefacts could be retrieved and demolition could be carried out safely.

Reinstatement

- Temporary stabilisation would allow the start of strengthening work and repairs as well as the more detailed investigation required for final detailed design.

- Strengthening would comprise a combination of techniques, including new concrete walls, repair of existing masonry, steel cross-bracing and base isolation, which would also provide greater protection for the heritage fabric.

- The cathedral's archaic materials make it impossible for the building to comply with every aspect of the new building code, but reinstatement could enable it to achieve 100 per cent of the code's seismic capacity requirements. The cathedral would then have the same capacity to resist collapse as that required for a new building.

- Repairs to the stonework could be accomplished by a variety of methods, according to the severity of damage and the extent to which full aesthetic restoration was required.

- Similar reinstatement methods are being successfully employed at the Christchurch Arts Centre.

- Similar strengthening techniques have been employed on Christchurch buildings that subsequently performed well in the earthquakes, most notably the Old Government Buildings (now the Heritage Apartments), the Art School at the Arts Centre and some blocks at Christ's College.

- Reinstatement work can be implemented with equivalent levels of worker safety to a normal construction site.

Indicative timelines and costs

- An early decision in favour of reinstatement would allow completion by the end of 2022, assuming standard design and procurement processes. A fast-track approach could shorten that time by 12 to 18 months.

- A decision in favour of replacement could result in a completion date of the end of 2019.

- If completed by the above dates, reinstatement would cost an estimated $105 million, and replacement with a contemporary cathedral of similar size and scale about $63 million (or $66 million with base isolation). These figures include contingency and escalation factors; they do not include GST.

- Both dates assume early agreement on funding and other key considerations, and no litigation over resource management, heritage or other issues. Litigation could push back completion many years, with obvious cost consequences.

ENGINEERING OPTIONS – SOME PRELIMINARY COMMENTS

The engineers' consideration of options has necessarily been high level, given engineering design proceeds by stages, each stage becoming a successively more detailed elaboration on the initial concept. This is especially so when developing a structural design for the repair and strengthening of a building.

An early concept design, when properly conceived by an engineer, will contain sufficient detail that an experienced quantity surveyor can produce a reliable budget. Other engineers, when "fleshing out" that design, may differ on the details, but the differences are generally inconsequential in any decisions about whether to proceed with a project, or its cost. Engineering and design assessment work completed since the earthquake has been to a level appropriate for estimation and planning. Both engineers agree further design work is unnecessary at present to enable a decision-making process.

In summary, it is neither necessary nor practical to attempt to supply too much detail too soon in the design process.

Terms

To an ordinary person, some of the terms used in this report are likely to have similar or identical meanings. "Restore" and "reconstruct" are good examples. But equally, such words can, to engineers and heritage professionals, have almost opposite meanings. "Restore" is again a case in point. To avoid confusion, the terms below have the following meanings for the purposes of this report:

- *restore:* to return the existing fabric of a building to its previous state without adding new material
- *repair:* to make good the decayed or damaged fabric of a building using identical, closely similar or otherwise appropriate material
- *reconstruct:* to return the existing fabric of a building to its previous state by using new material
- *retain:* to keep intact the original features and materials of a property.

Available engineering options

The terms of engagement seek a consensus on engineering options for the building. Since construction of a replacement cathedral presents, from an engineering perspective, no particular difficulties, the focus of this report is on repair or restoration, as set out in issue three below. The experts describe this as "reinstatement", that is, a combination of repair, restoration, reconstruction and seismic strengthening. Replacement – the alternative to reinstatement – could result in a totally new building or it could include adaptation of some existing parts of the building.

Adaptation means the process of modifying a place for a compatible use while retaining its cultural heritage value. Adaptation can include alteration and addition. An adaptation approach could include reinstatement of only parts of the cathedral, alongside replacement of other sections in alternative forms and materials. If substantial portions of the cathedral are to remain, the design of new sections will have to satisfy the adaptation principles of the ICOMOS New Zealand charter by being sympathetic to the remaining reinstated portions.

An adaptation approach would probably be applied to the tower, at least in the upper levels, because of the level of damage and volume of stone in the original steeple. This could involve reconstruction of the lower portion of the tower to more closely resemble the original construction, with replacement of the upper section in new lighter materials. This approach could also be extended to other areas and could, for example, allow for adaptation within the nave, ranging from minor modifications to a completely new one, to accommodate the Church's needs (such as better acoustics, access for the disabled and more flexibility in the way the space can be used).

ISSUE ONE: LEVEL OF DAMAGE AND RISK WITH THE PRESENT STRUCTURE

Current condition

Since the earthquakes, Church Property Trustees' engineers have assessed the cathedral's structure through:

- reasonably regular external surveys over the past five years, the most recent of which occurred in 2014 (These included comparison of tell-tale marker strips applied over cracks in key locations to assess movement.)

- limited 3D laser point cloud scanning of key areas of the building

- limited interior visual surveys, the last of which occurred in 2012.

Engineers for the Great Christchurch Building Trust have also had opportunities to carry out external inspections and review interior photographs.

The following descriptions of damage are based on these assessments. Subsequent closer inspections will undoubtedly uncover further, unseen damage, but such damage would not alter the conclusions of this report.

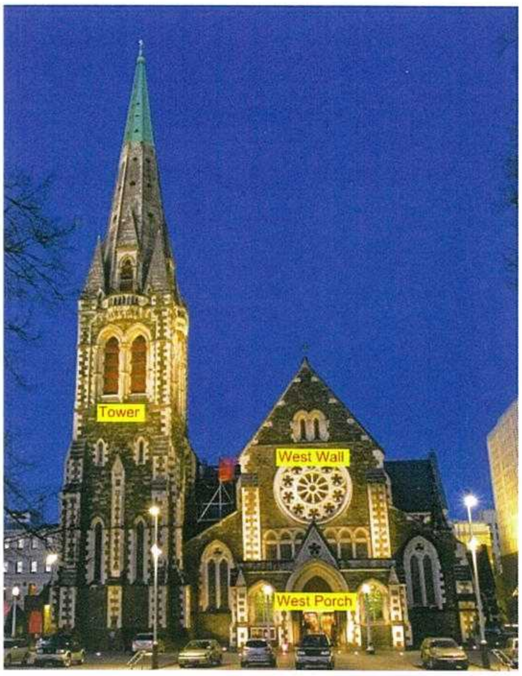
Portions of the tower and west wall have collapsed or have been substantially demolished. Other parts are damaged to varying degrees as summarised below. In particular, the earthquake motion caused relative movement between the upper part of the building and the foundations, resulting in a zone of damage that is mostly concentrated in the walls between the eaves and sills. The damage typically consists of lines of cracking, the crack widths varying from a few millimetres to about 60mm. There are some areas of residual offset.

The roof structure appears to be largely intact. Earthquake-strengthening work completed in 1999 and 2003 apparently proved effective in tying the building together and preventing more serious damage and collapse.

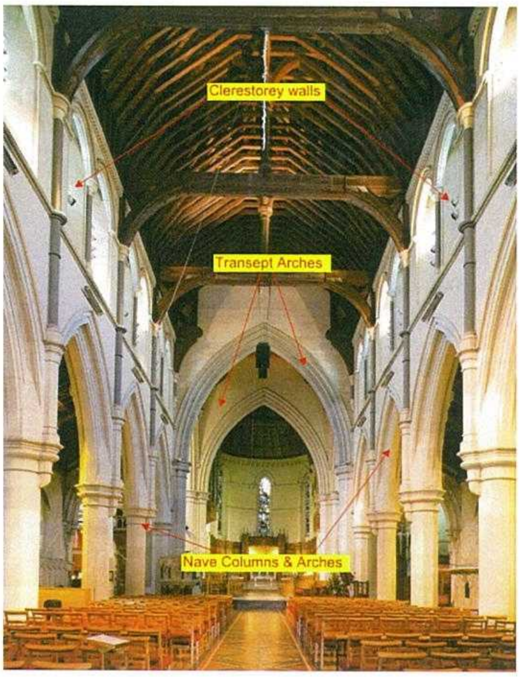
In short, the damage renders the cathedral hazardous for use until it is reinstated or replaced.[5] It also requires temporary stabilisation before workers can enter safely.

Photographs, together with elevational drawings containing crack and damage mapping (Appendix 2), illustrate the present extent of damage. A ground floor plan is set out below to show the location of the various parts of the cathedral for the purposes of identifying damage.

[5] The cathedral is the subject of a s 38 notice issued by CERA under the Canterbury Earthquake Recovery Act 2011 on 28 October 2011 requiring the owner to undertake demolition work to make the cathedral safe in terms of the Building Act 2004. Apart from deconstruction of the tower, no work has been carried out under that notice.



Western elevation



Interior view

Figure 1: Before the earthquakes

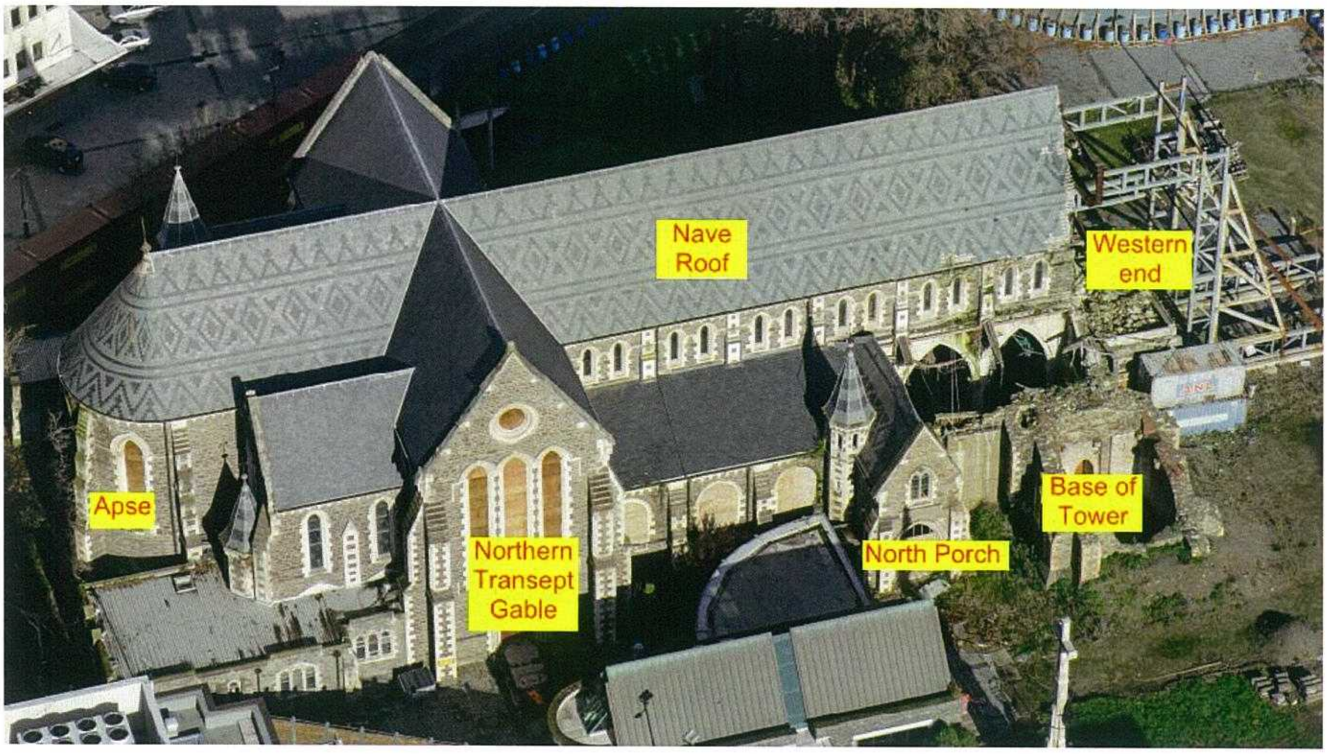


Figure 2: Current view from the north

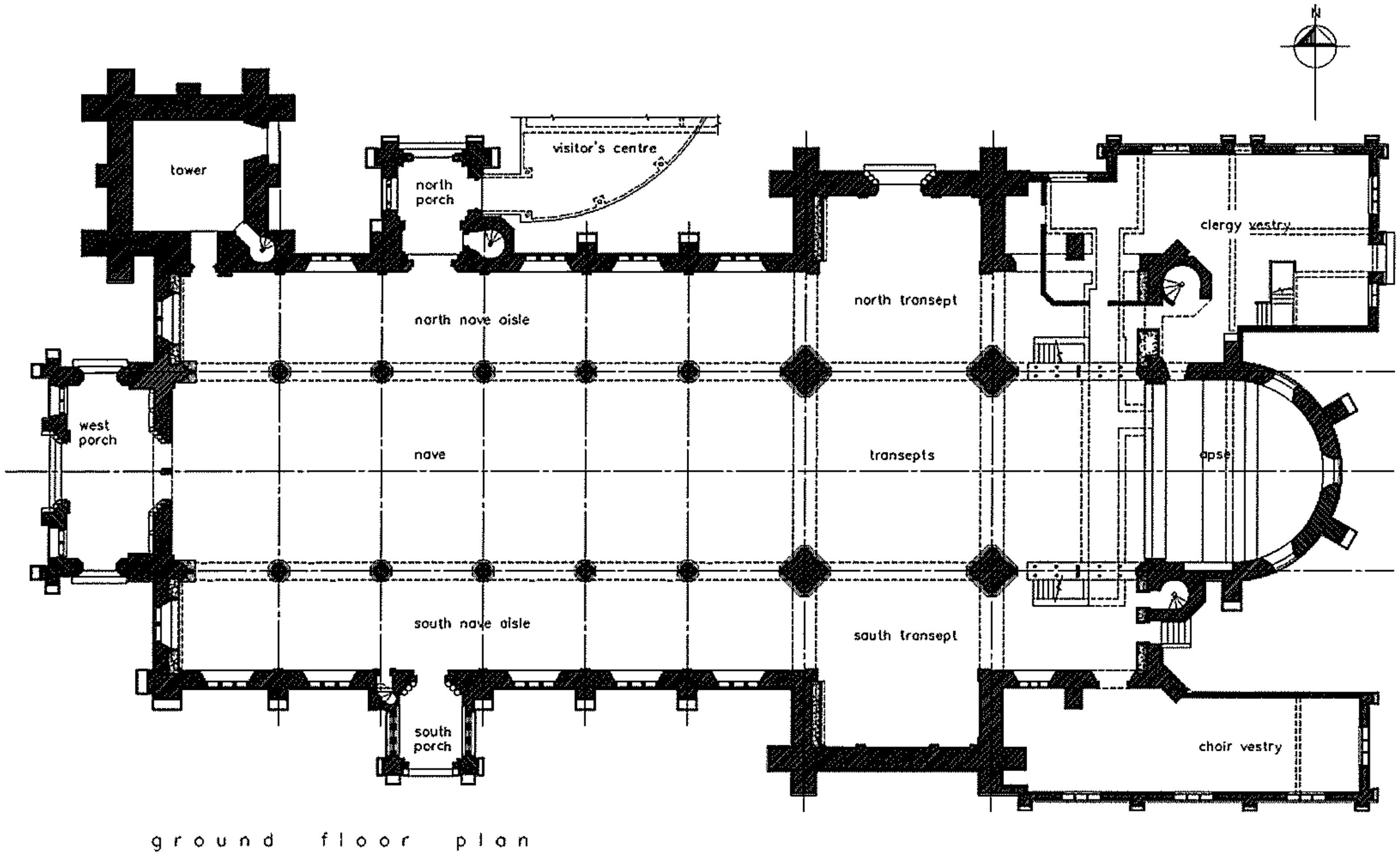


Figure 3: Floor plan

West porch

The west porch is permanently offset from the west wall by between 20mm and 30mm. There is moderate damage to the south and west walls and significant damage to the north wall. Damage to this last wall includes parapet collapse and significant spalling (loss of small pieces of masonry) of the north-west buttress. The north portion of the roof collapsed as a result of falling tower debris.

Figure 4: Damage observed to the west porch

West wall

The west wall is significantly damaged. The top portion, including the rose window and buttresses, has totally collapsed. The remainder is distorted. The end walls to the side aisles are less damaged. The parapet capping stones were removed in 2011, and plywood panels in front of these walls act as protective screens to the windows. The concrete shear walls (inserted in 1999) were probably effective in preventing further damage.

Figure 5: Damage observed to the western end

Tower

The tower, which substantially collapsed in the earthquakes, has been demolished to almost ground level.

Roofs

The north aisle roof has collapsed at the western end as a result of falling tower debris. The south aisle roof bracing has stretched and is visibly sagging. A bracing truss connection has been lost at the junction with the south porch.

There is a relatively small area of damage to the main nave roof where the west wall collapsed. There is little visible damage to the original roof cladding and structure in areas away from the tower and west end collapse.

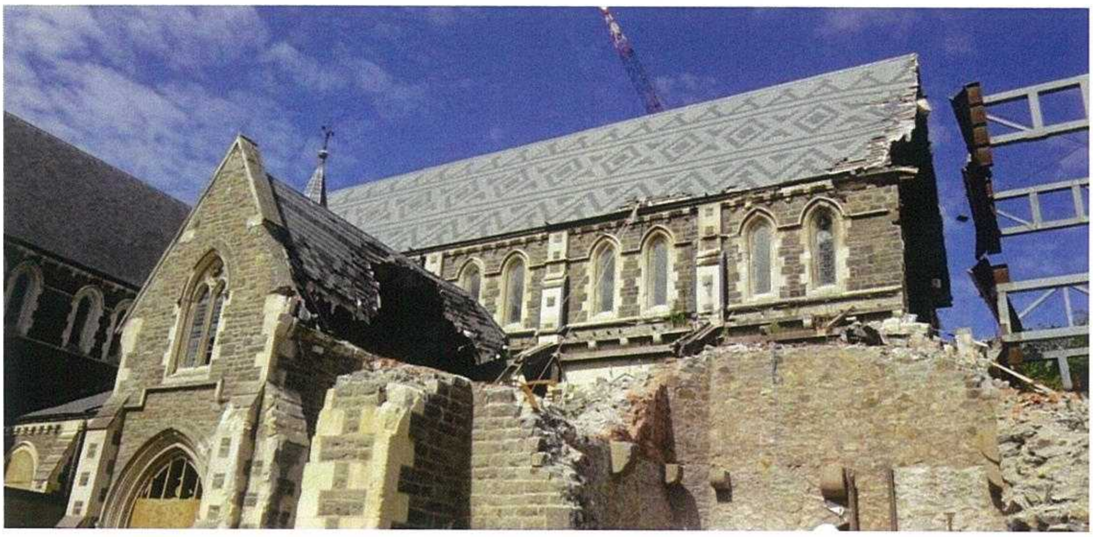


Figure 6: Damage observed to the north aisle roof

North aisle wall

The north wall has cracking through the wall piers and buttresses of between 5mm and 15mm.

Figure 7: Damage observed to the north aisle wall

South aisle wall

South wall piers and buttresses show damage similar to that observed in the north wall. However, the cracks are significantly wider (10mm to 50mm). Wider cracks in the buttresses indicate increased degradation of the walls. The projecting faces of two buttresses were removed from the face of the wall for safety. Some glass damage has occurred as a result of the structural deformations.

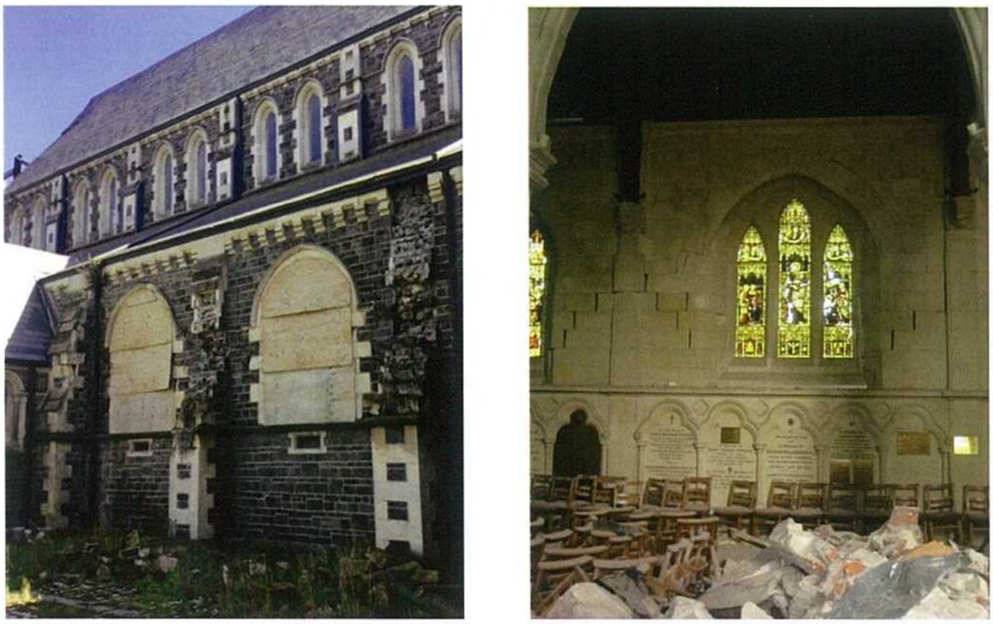


Figure 8: Damage observed to the south aisle wall

Nave

High-level clerestory walls in the north-west corner have an outward lean as a result of the tower collapse. There is minor to moderate cracking in other areas of the north clerestory walls. No significant structural damage appears to have occurred to the south clerestory walls. Nave columns and arches have varying degrees of damage and dislocation, reflecting movement in the clerestory walls above.

Figure 9: Damage observed to an arch and column within the nave

Figure 10: Tower debris within the nave

North porch

The west wall and buttresses of the north porch are damaged from falling tower debris. Stone elements that make up the north gable end have surface damage. Falling tower debris has caused much of the west side of the north porch roof to collapse. Cracks can be observed in the ceiling.

Figure 11: Damage observed to the north porch

A significant amount of tower debris has fallen through the north porch roof and remains on the existing attic floor. The north turret appears to be generally in good condition but with some glass breakage. There is minor cracking (1mm to 3mm) in the supporting stairwell walls.

South porch

The south porch is generally in good condition except for severe damage to the stairwell wall that supports the south turret. The turret was removed to the grassed area to the south of the cathedral in early March 2011.

Figure 12: Damage observed to the south porch, and relocation of the south turret

Transept walls

The north and south transept walls have cracking and dislocation. The upper regions have a residual horizontal offset of between 30mm and 60mm for the north and south walls respectively. The north and south transept wall gables have a perceptible lean outwards.

Figure 13: Northern transept gable wall and southern transept gable wall damage

Transept interior

The central transept area has suffered damage from transverse motions. There is severe damage to the west arch where it forms the junction to the nave. Immediately after the earthquake, temporary strapping was added to the damaged masonry columns that support the transept arches.

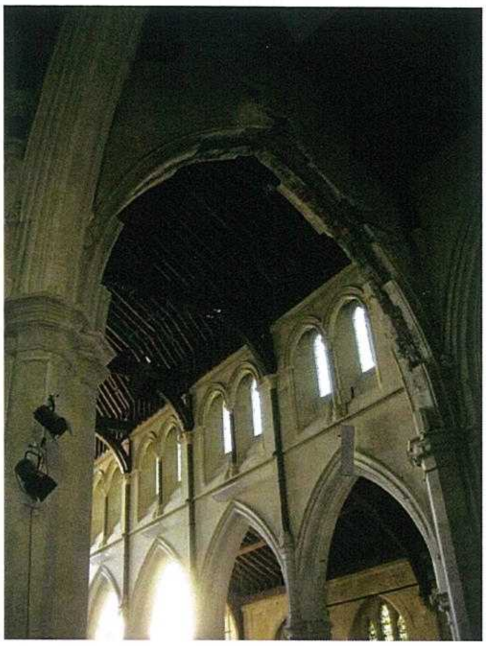
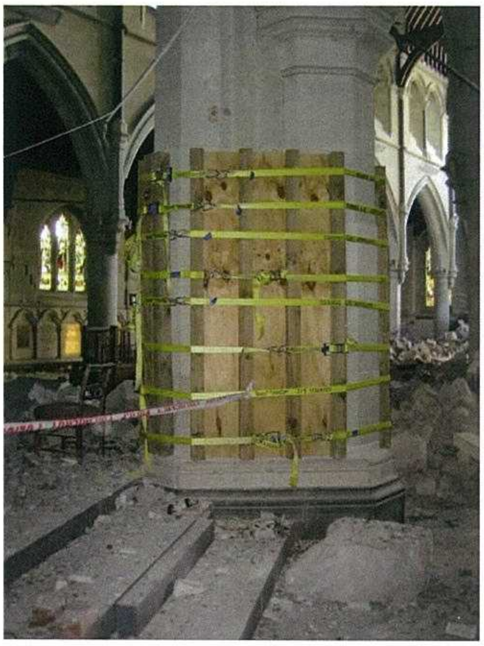
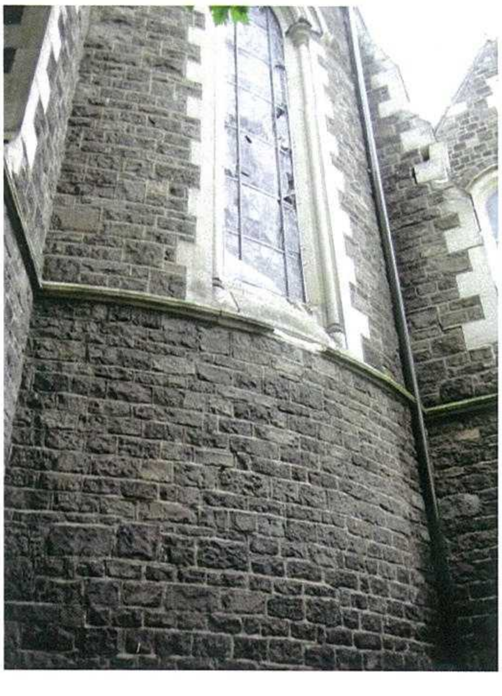
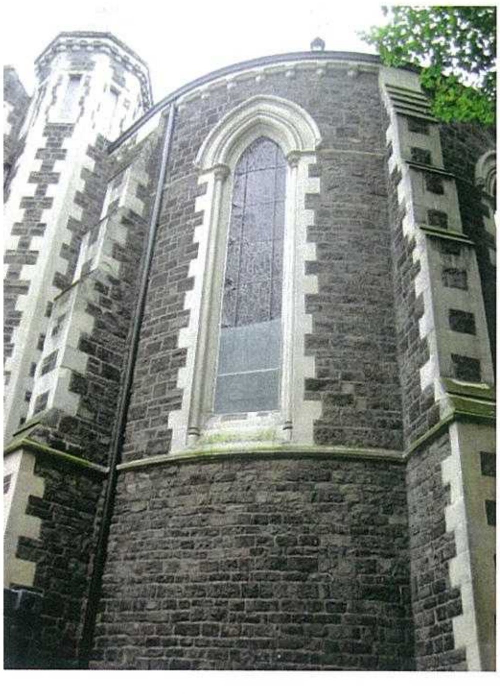



Figure 14: Damage observed in the transept (from 2012)

Apse

The north and south apse walls have cracking of about 50mm and 20mm respectively. There is associated glass damage. The central east wall is less damaged.

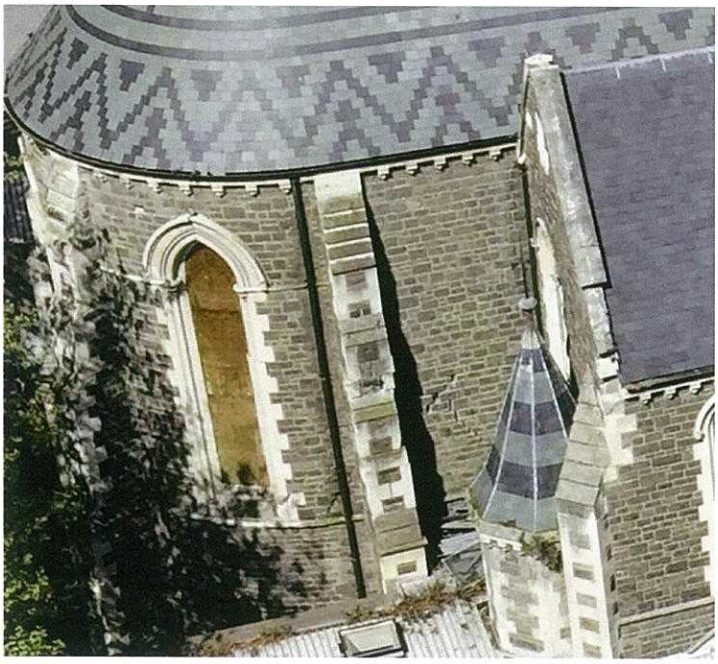


Figure 15: Damage observed to the apse

Clergy vestry

The north and east walls, believed to be of reinforced concrete, are largely undamaged. The south wall, believed to be a plastered concrete block infill wall, has minor cracking. The original unreinforced masonry walls have cracking as well as permanent offset of about 50mm, much like that to the apse.

Figure 16: Damage observed to the clergy vestry

Choir vestry

Damage is similar to that seen to the clergy vestry.

Foundations

Results of a geotechnical examination by Tonkin & Taylor in September 2011 suggest:

- no significant settlement or differential settlement of the foundations
- no liquefaction or lateral spreading in the immediate area of the cathedral.

A preliminary liquefaction assessment indicated that free-field settlements of up to 20mm might have occurred during the February 2011 earthquake.

Risks posed by the cathedral's current condition

These are summarised as follows:

To the public

There is negligible risk since the site is fully fenced, and a steel and timber barrier wall at the east end is designed to ensure trams can pass in relative safety. In the event of another severe earthquake that resulted in partial collapse, debris is likely to be contained within the site. As with any dangerous site, the cathedral presents a hazard to anyone entering the site without authority. The owner has installed video surveillance to deter such entry.

To workers

The cathedral currently poses hazards to anyone entering the site, including workers. There are risks of unstable and falling masonry, especially in the event of further earthquakes. There are health hazards arising from infestation. There may also be undetected hazards such as asbestos, which may become evident only when work starts.

To the cathedral

Left in its current exposed and weakened state, the cathedral is at risk of deterioration and further seismic damage. Such damage could range from widening of cracks to partial or total collapse. Deterioration is most likely to occur as a result of exposure of open sections at the west end to weather and infestation (particularly pigeons). Plants continue to grow on or about the cathedral, which may cause damage, although it is unlikely to be severe in the short term. Water damage may cause timber structures to rot. Staining of the stone may also occur.

ISSUE TWO: WHAT IS REQUIRED TO MITIGATE ANY RISKS AND ENSURE SAFE ACCESS TO INVESTIGATE REPAIR, RESTORATION OR REPLACEMENT OPTIONS?

A decision on whether to reinstate or replace requires no further investigation of the cathedral's interior. The nature of the building is such that the damage and its impact can be adequately evaluated on the basis of what is already known.

Once a decision is made, however, on the cathedral's future, mitigating risks to workers on the site will be critical.

If the decision is to reinstate, temporary stabilisation will be necessary to enable permanent seismic strengthening, repair and restoration work to begin. If the decision is to replace, less temporary stabilisation will be needed before demolition can begin. The amount will depend on the extent of artefact retrieval and recovery of building materials and the extent, if any, of asbestos contamination.

The mitigation measures of each course of action are briefly considered below.

Reinstatement

Temporary stabilisation to ensure worker safety is critical, both during the further investigative phase and during reinstatement work itself. Stabilisation work will enable the following to occur:

- an accurate survey
- the inspection and recording of damage
- a detailed structural assessment
- testing of existing materials for strength and other matters
- the retrieval of artefacts
- actual strengthening and repair work.

The cathedral has hazards not present on a typical construction site that would require the development and adoption of specific management procedures. The objective would be to provide assessment and construction personnel with a level of safety that met their health and safety obligations, and those of their employers, consistent with a comparable construction site.

In short, worker safety would be paramount. With the full collaboration of all parties involved, such an outcome can be achieved. There remains, however, the risk of harm in the event of a major earthquake, a risk that would be impractical to mitigate fully – just as it would on any building site.

Temporary stabilisation would not make it possible for the public to enter the site, which would be subject to construction site hazard management protocols appropriate for the site in full compliance with pending changes to health and safety legislation.

Temporary stabilisation

This would consist of inserting a supplementary structure to support and brace the existing structure. It would provide vertical support to elevated elements, such as roofs, arches and the clerestory. This support would provide alternative load paths in the event of failure or the removal of existing structure. It would also brace the overall structure and individual elements (for example, walls) against anticipated lateral loads, such as seismic movement and wind.

The supplementary structure would be erected both inside, and around the exterior of, the building. In addition to supporting load-bearing elements, it would provide access and work platforms throughout the building, together with protective screens to guard against falling masonry.

At the same time, hazardous and vulnerable building elements would be pinned in place or removed and stored while stabilisation and strengthening work was completed. Such elements would include capping stones, turrets and vulnerable ornamentation at risk of toppling or being damaged during reinstatement.

Implementation

The parties' engineers disagree about precisely how temporary stabilisation would be implemented, but not about what conceptual form stabilisation should take. The disagreement is not material to the outcome of this report, given both engineers agree that a viable technical solution is possible at a roughly similar cost.

Temporary stabilisation would be installed progressively to provide protection to workers throughout the installation process. Various methodologies could be used, but work would probably start with internal access through the western end, in conjunction with the positioning of external bracing frames.

A conceptual scheme has been developed that would enable the west porch and nave gable wall (both severely damaged) to be cleared to provide the main access to the building's interior.

A skeletal steel frame, complete with elevated walkways and protective overhead screens, would then be progressively inserted from the west end, so that all work was completed through a stabilised structure. Detailed assessment, strengthening and repair work could follow behind each step in the stabilisation process.

Pinning or removing dangerous and vulnerable elements can generally be completed externally, either using a crane or from elevated platforms, working down from the highest level as the adjacent areas are stabilised and/or secured.

Similar forms of temporary stabilisation to those discussed here are in use at the city's Arts Centre and for seismic strengthening of Wellington's Saint Mary of the Angels.

The cost of temporary stabilisation

This has been estimated at $9.625 million: see Appendix 3.

Safety during temporary stabilisation

Temporary stabilisation should progressively provide a level of performance that satisfies building code requirements for temporary and short-term building structures. This would provide an appropriate level of protection for worker safety during reinstatement.

Replacement

If the decision is to replace the cathedral, the extent of temporary stabilisation will vary according to the extent of artefact retrieval and recovery of building material. The exact form of that stabilisation will depend on the location of the artefacts and the extent to which the artefacts are put at risk during the process of recovery. The envisaged approach is to protect the artefacts so they can be removed after deconstruction or demolition. This avoids exposing workers to risk from falling masonry.

The budget estimate in Appendix 3 allows for limited protection while recovering stained glass, the Harper effigy, the pulpit and parts of the organ. The indicative cost is

approximately $2.4 million. More extensive recovery would add to the extent of temporary stabilisation required, and hence its cost. In the unlikely event of widespread asbestos, more extensive temporary stability may be required for its safe removal.

Health risks

Procedures will have to be adopted by the contractor to manage the health hazards resulting, for example, from pigeon or rat droppings, until such time as the affected areas can be suitably decontaminated. Asbestos testing will be necessary as potentially contaminated areas are stabilised. Decontamination procedures, if necessary, may include the use of protective clothing and breathing apparatus until the area can be stabilised enough to carry out mitigation work. These procedures are typical for management of contaminated sites.

ISSUE THREE: CAN THE CATHEDRAL BE REPAIRED OR RESTORED IN WHOLE OR IN PART TO 100 PER CENT OF THE NEW BUILDING CODE?

Introduction

From an engineering perspective, the cathedral can largely be reinstated. The parties' engineers prefer the term "reinstated" to "repaired" or "restored" because it would be impossible, from an engineering perspective, to rely solely on repair methods or on restoration methods to bring the cathedral up to full building code. Reinstatement, as already noted, employs a combination of repair, restoration, reconstruction and seismic strengthening.

Because the cathedral is constructed of archaic materials, it can never fully comply with New Zealand's building code, which specifies the required performance of buildings, in all respects.[6] However, reinstatement could achieve 100 per cent of seismic capacity as required by the code, that is, the cathedral would achieve the same level of safety from structural collapse that would be required for a new building.

The tower and west wall are substantially demolished. The way they collapsed or were demolished means no record could be kept for removal or reconstruction purposes. Many elements were damaged beyond repair. Reinstatement here would follow a similar process to the rest of the cathedral, but with the introduction of significantly more new material and probably, as already noted, a lighter upper section.[7]

Reinstatement is not a novel or untried process. The Arts Centre is being reinstated using the same combination of techniques. For example, the Clock Tower building at the Arts Centre has been reinstated, including the insertion of reinforced concrete walls, which have been clad in a combination of the original masonry and new masonry elements in the same form. To most people, the outcome will be virtually indistinguishable from the original pre-earthquake building.

How reinstatement is carried out

Following temporary stabilisation (outlined in the previous section), work would take place to strengthen the cathedral, carry out base isolation (as a specific and specialised strengthening technique) and repair stone masonry.

Strengthening work would require the introduction of extensive new structure into the existing building fabric to achieve the stated objectives. It is not feasible to repair and strengthen the cathedral to the required performance level without adding new materials.

The existing walls were constructed using traditional masonry techniques of the time. Inner and outer wythes of cut stone were mortared into place and the gap between was filled with a weakly cemented random rubble infill. Such walls are subject to both in-plane (shear) actions and out-of-plane (face-loading) actions. The newly introduced structure should be of similar or greater stiffness to minimise damage to the existing structure from displacements caused by future earthquakes. The new structure would be typically concealed between the inner and outer wythes of stone and ashlar.

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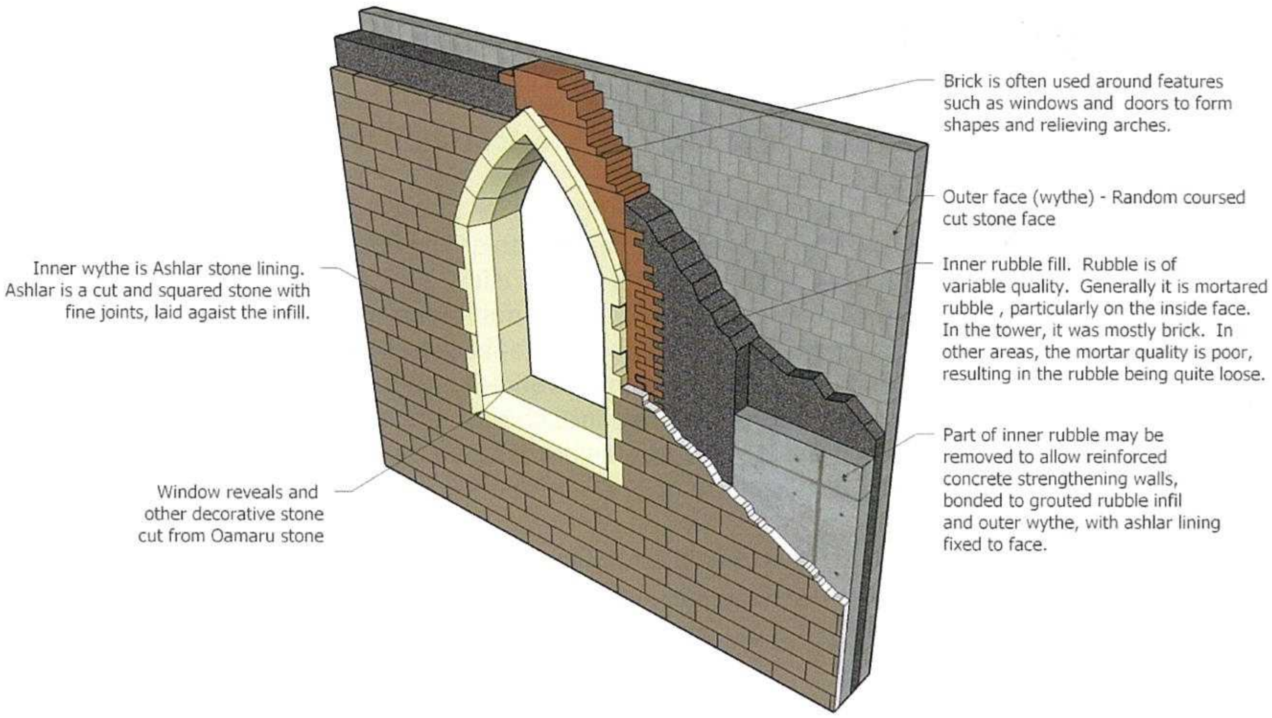
[6] See Schedule 1 to the Building Regulations 1992.

[7] See page 8.



Typical cathedral wall construction

Seismic strengthening techniques

Strengthening would probably involve a combination of techniques, including:

- *reinforced concrete wall/frames:* These would be inserted into the existing walls through a process of removal of the ashlar interior facing and part of the rubble infill. The reinforced concrete could then be cast against the remaining stonework before replacement of the ashlar facing, concealing the new concrete.
- *grouting of the stonework:* This entails pumping of concrete grout under low pressure into the weakly cemented rubble infill.
- *centre-coring:* Holes are drilled down the centre of solid or grouted masonry walls to insert reinforcing, which is grouted in place. This reinforcing may be post-tensioned to improve resistance to displacement.
- *fibre-reinforced composites (FRP):* FRP is a thin layer of fibreglass or carbon fibre reinforcing that can be applied to the face of stone walls or epoxied into slots cut into the wall.
- *structural steel:* Structural steel would be used primarily in bracing elements, such as in the roof, where more bracing would be required, and in tie elements that might be needed to augment some of the existing structure, such as roof elements.
- *base isolation:* Base isolation involves creating a separation plane, typically below the ground floor, into which bearings are placed that fully support a building's weight, but which significantly reduce the transmission of lateral seismic actions to the building above the isolation plane. A moat, or "rattle-space", is required around the building to allow full movement of up to 500mm, but which can be covered with sliding plates for appearance, access and safety. Deeper excavation would be needed to install the base isolation except in those areas that already had a partial basement.

Preliminary scope of strengthening work

A high-level description of the overall scope of such work is as follows:

- new steel cross-bracing to the high-level roof of the nave, transepts and apse, either in the sloping plane of the roof, or horizontally at the level of the tops of the masonry walls
- replacement steel bracing with augmented connections in the roof plane over the side aisles to upgrade or replace the strengthening inserted in 1999
- reinforced concrete infill walls to the transept, apse and side aisle walls, extending down to the existing foundation level
- reinforced concrete buttresses, clad with original masonry, to replace the existing buttresses, tied through to the new reinforced concrete walls
- new reinforced concrete foundation beams cut into and sandwiching the existing foundations, in two layers to permit installation of the base isolation
- new reinforced concrete or FRP overlays to the upper-level clerestory walls along the nave
- repair and protection of the stone columns to the nave
- the addition of ties between existing and new elements to complete load paths to provide support to all of the parts of the building (Examples include gable ends and the tops of walls that must be tied back to the supporting roofs, possibly with additional steel supporting members where spans are too great.)
- pinning and securing of vulnerable exterior and interior ornamentation, such as parapet capping stones, finials, window mullions and stone panels
- install a base isolation system to the entire building.

The less heavily loaded walls, such as at the rear of the building adjacent to the apse, might possibly be upgraded using only grouting and centre-coring for a less intrusive outcome, or might require no work at all.

These techniques would be considered conventional strengthening and have been employed successfully on buildings in Christchurch that performed well during the earthquakes. Notable examples include:

- the Old Government buildings (now Heritage Apartments), which were strengthened using concrete walls in 1995 to 75 per cent of the building code of the time (minor damage in 2011)
- the Arts School at the Arts Centre, which was strengthened in 2009 to 67 per cent of the building code of the time using a combination of techniques, including FRP overlays (minor damage in 2011)
- Christ's College, several blocks of which were strengthened to up to 67 per cent using a range of techniques (such blocks performed well in 2011 and the school was able to remain open while repairs continued).

Work would take place progressively, with strengthened portions of the cathedral providing extra support for adjacent non-strengthened areas and allowing removal and reuse of the temporary steel bracing elements. In this way, appropriate levels of safety could be continuously maintained rather than having large work-faces open and unsupported, even for short periods.

Base isolation

Base isolation would provide greater protection for the heritage fabric. It would minimise the introduction of new strengthening structures and provide greater safety for occupants. It may

be argued that if the existing building warrants reinstatement, then it also merits the higher damage avoidance that comes with base isolation.

It is likely that all, or most, of the structural strengthening and restoration work would be completed before base isolation to reduce the risk of damage during excavation. In that case, strengthening to 100 per cent of building code would not be achieved until completion of base isolation.

Base isolation of heritage buildings following this general method was used, for example, in the strengthening work on New Zealand's Parliament. Although not commonplace in New Zealand, it is an internationally accepted practice, often preferred in cases where there are either valuable contents or heritage buildings that need protection.

Replacement of the cathedral with a contemporary one may also warrant base isolation for added protection of the building and valuable contents. The replacement option has been costed with and without base isolation: see Appendix 3.

Stone masonry repair

Repairs to the stonework could be accomplished using a variety of methods, according to the severity of damage and the extent to which full aesthetic restoration was required.

Where damage was minimal, or the appearance allowed, stonework could be repaired in place. Temporary support would be needed to the face of the stonework in question, after which the interior ashlar stone lining and rubble infill could be removed and reinforced concrete inserted, as described above. This technique has been employed extensively at the Arts Centre during reinstatement work.

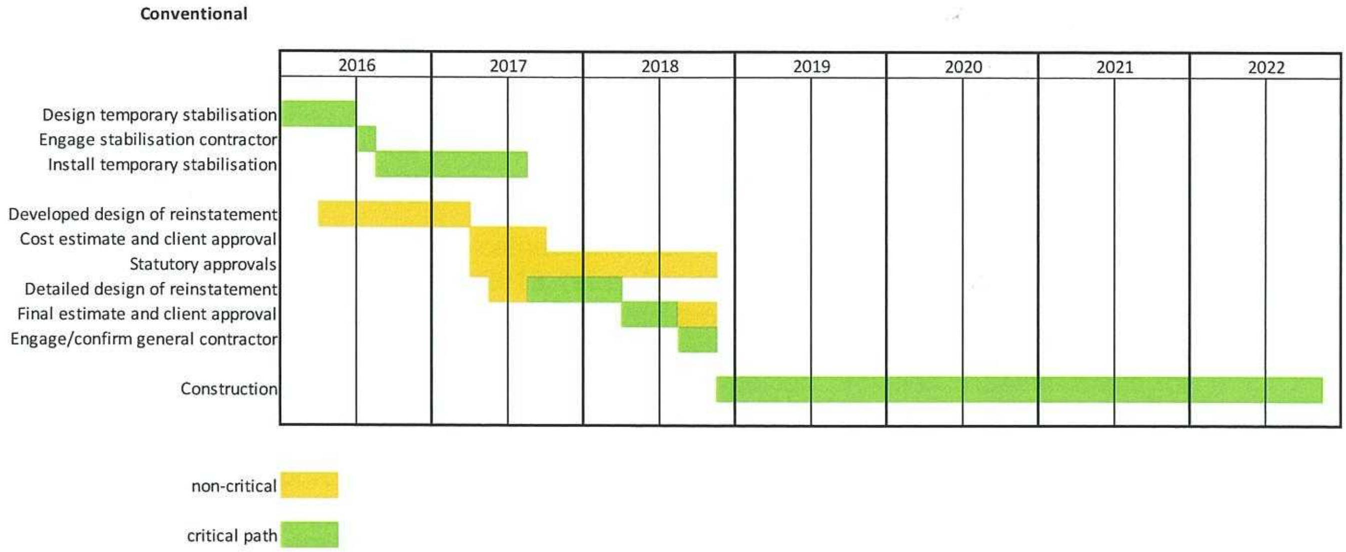
Where the damage or displacement was regarded as too great, the stonework might need to be deconstructed, recording the locations of all of the removed stone (again, as done at the Arts Centre). The stone could then be reconstructed, incorporating the reinforced concrete infill as construction advanced. Depending on the location, this might be more economically done by removing all stone above the damaged area and rebuilding the entire section of wall, or by propping and bracing the stone above the damaged area and rebuilding only the damaged portion. This decision could vary according to cost and/or heritage priorities.

Stone masonry capability in Christchurch is of a very high standard. The city's stone masons are highly experienced in repair and replacement work in a way that preserves the heritage appearance of historic buildings.

A replacement tower could have a number of structural forms that would probably include reinforced concrete and/or structural steel. It could be clad in salvaged and/or new stonework.

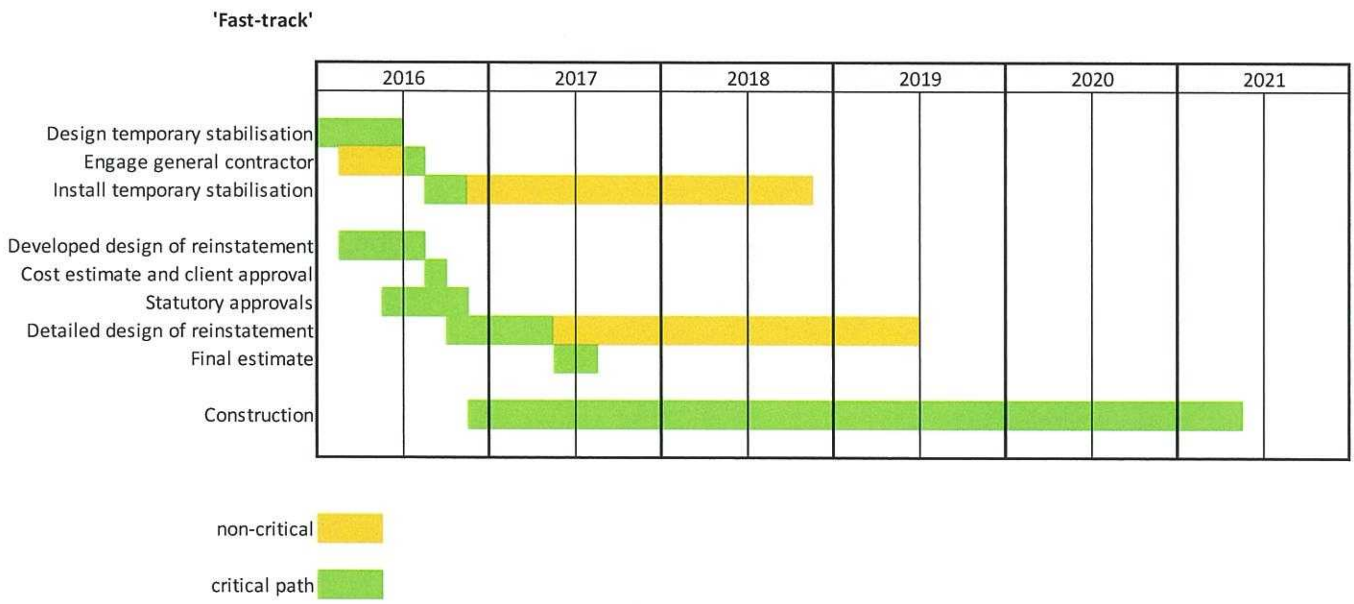
Indicative timing

An early decision to reinstate the cathedral would allow completion following standard design and procurement processes by the end of 2022.



A fast-track approach could cut 12 to 18 months off the finish date. This would entail some simultaneous temporary stabilisation and early construction work. Design work would proceed in parallel with stabilisation and construction. Costs and time frames would be less certain until after construction work began, but this approach would offer the prospect of a shortened and less costly process.

If this approach were followed, any delays in obtaining statutory approval would have serious implications for meeting the earlier deadline. A collaborative process between the main contractor and consultants will be essential.



Indicative costs

The parties' quantity surveyors met in May this year and agreed on an indicative cost of $105 million to largely restore the cathedral. (This figure, like all others, excludes GST.) The quantity surveyors have reviewed the May estimate and consider this figure is valid for reinstatement of the cathedral. It includes contingency and escalation factors.

An indicative cost for replacement of the cathedral with a contemporary one of a similar size and scale is estimated at $63 million by Church Property Trustees' quantity surveyor, David Doherr, or $66 million with base isolation. The Great Christchurch Buildings Trust's quantity surveyor, Julian Mace, has not undertaken an estimate of the costs of replacement, but he is satisfied that $63 to $66 million is a realistic cost for a replacement cathedral of a similar size and scale. Again, it includes contingency and escalation factors.

The indicative cost of a replacement cathedral is based on an early design by architectural firm Warren and Mahoney in May 2013 (see Appendix 3). Delays will lead to further escalation. The Warren and Mahoney design was merely one option for a contemporary cathedral of a similar size and scale. The precise design of any contemporary cathedral will heavily influence costs. But the Warren and Mahoney design provides a useful basis for indicative costs.

Appendix 3 provides approximate costs for both options, which the engineers rely on for the purposes of this report. These indicative costs depend on the timelines given above. It is emphasised that they are indicative only. Actual costs may ultimately be less or more for either option depending on various factors. As but one example, consents for demolition may prove more difficult and costly than estimated, especially if litigation ensues, in the event the replacement option was adopted.

Other matters

Whether the cathedral is reinstated or replaced will require consideration of a range of other non-engineering matters. Broadly, these are:

- *spiritual:* the spiritual dimensions of the cathedral and its use, especially the need for flexible and appropriate liturgical space
- *commercial:* such factors as funding, risk of overruns and management of the work
- *maintenance*: including the funding of future maintenance
- *insurance*: availability and cost during and after reinstatement
- *legal:* compliance with statutory and regulatory requirements, including approval processes and legal responsibility for health and safety
- *heritage and aesthetic considerations:* whether evidence of earthquake damage should be left evident or removed.

None of these matters are, under the terms of engagement, for the engineering experts.

Miriam R Dean CNZM QC
Facilitator

John Hare
Holmes Consulting Group

Adam Thornton
Dunning Thornton Consulting group

12 November 2015

APPENDICES

Appendix 1
Engagement Appointment of Miriam Dean QC

- **facilitate discussions with engineers engaged by the Church Property Trustees and the Great Christchurch Buildings Trust (the parties) on engineering options for repair, restoration or replacement of ChristChurch Cathedral, and**
- **report to the Government (through Ministers) on the outcome of those discussions.**

Background

1. The Government is concerned that the regeneration of Christchurch is being unduly delayed by indecision over the future of ChristChurch Cathedral.

2. The Government recognises the legitimate and obvious ownership interests of the Church Property Trustees, and the concerns of the Great Christchurch Buildings Trust, regarding the future of the Cathedral.

3. ChristChurch Cathedral is also important to the people of Christchurch, Canterbury, and New Zealand. The Government is concerned to ensure that decisions as to the Cathedral's future appropriately reflect the wider significance of the Cathedral, and are undertaken in a timely way.

4. Recognising this concern, representatives of the Government recently met with each party, on a confidential and without prejudice basis, to discuss the future of the Cathedral and the possibility of a compromise between the parties for the benefit of Christchurch (and New Zealand generally), before any precipitate action becomes necessary.

5. The Government is encouraged by the indications from each party at those meetings that a reasonable compromise is achievable.

6. The Government considers a logical first step is to facilitate a consensus between the parties' engineers on the current status of the Cathedral.

7. Specific matters the Government wishes the engineers to address include:

   a. The level of damage and risk associated with the present structure of the Cathedral.

   b. What is required to mitigate any risk and ensure the present structure is safe so that people are able to access the Cathedral to undertake investigations on repair, restoration or replacement options?

   c. Whether the Cathedral can be repaired or restored, in whole or in part, to 100% of new building codes.

APPOINTMENT

8. The Crown has accordingly appointed Miriam Dean QC to facilitate discussions amongst the parties' engineers, to encourage them to come to a consensus on the matters referred to above.

9. After meeting with the parties' engineers Ms Dean will report to the Minister for Canterbury Earthquake Recovery and the Attorney-General (the

Ministers) on the outcome of those discussions and the Government will then determine the next steps.

10. At this point the Government does not seek any recommendation from the engineers as to which option could be pursued, although it does seek approximate indications of the cost of any available options. However, a key element required by the Government is that any option for repair or restoration of the Cathedral must be one that meets appropriate safety standards.

A.1 PROCESS

11. Ms Dean will:

   a. Advise the parties of the process she proposes to adopt in order to seek the consensus referred to above.

   b. Invite the parties' comments on that process, but on the basis that process will ultimately be determined by her.

   c. Meet with the parties' engineers as soon as may be conveniently arranged.

   d. Conduct the process with the engineers on a without prejudice and confidential basis, subject to the reporting exception noted below, and any other exception that may be permitted by the process.

   e. If appropriate, seek further engineering advice, which she can determine whether or not to provide to and test with the parties' engineers.

   f. Prepare a report on the outcome of the process to the parties and to the Ministers.

12. The Government expects the parties and their engineers will engage in this process in good faith, and that the parties' engineers will actively and constructively seek a consensus on the engineering options that are available to restore, repair or replace the Cathedral to a safe standard.

13. With the prior approval of the Government, Ms Dean may engage an engineer to assist her in conducting the process, or in reporting to the Government, if she considers that necessary or desirable.

14. The parties' engineers will be able to report on the process to a nominated representative of their respective clients, and to their clients' legal advisers, but will otherwise keep the process confidential (as will the nominated representatives).

15. The Government may wish to disclose the outcome of the process publicly in order to facilitate the objectives referred to above, but will endeavour to consult with the parties before making any such disclosure.

16. Ms Dean's costs will be met by the Government. The cost of the parties' engineers' involvement in the process is to be met by the parties.

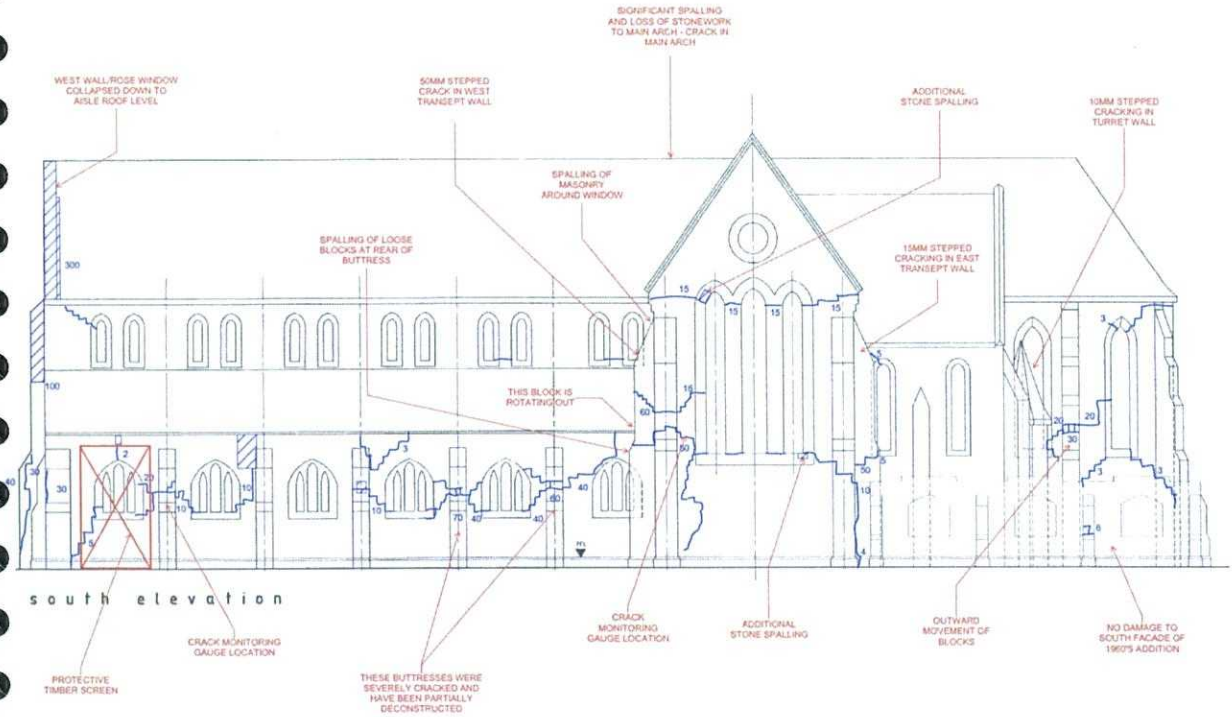
ASSISTANCE

17. Ms Dean will be assisted by staff from the Crown Law Office and, if appropriate, Canterbury Earthquake Recovery Authority staff.

REPORTING SEQUENCE

18. Ms Dean may begin as soon as convenient, and will report to the Ministers in writing by 30 November 2015.

Appendix 2
Diagrams mapping damage and cracking



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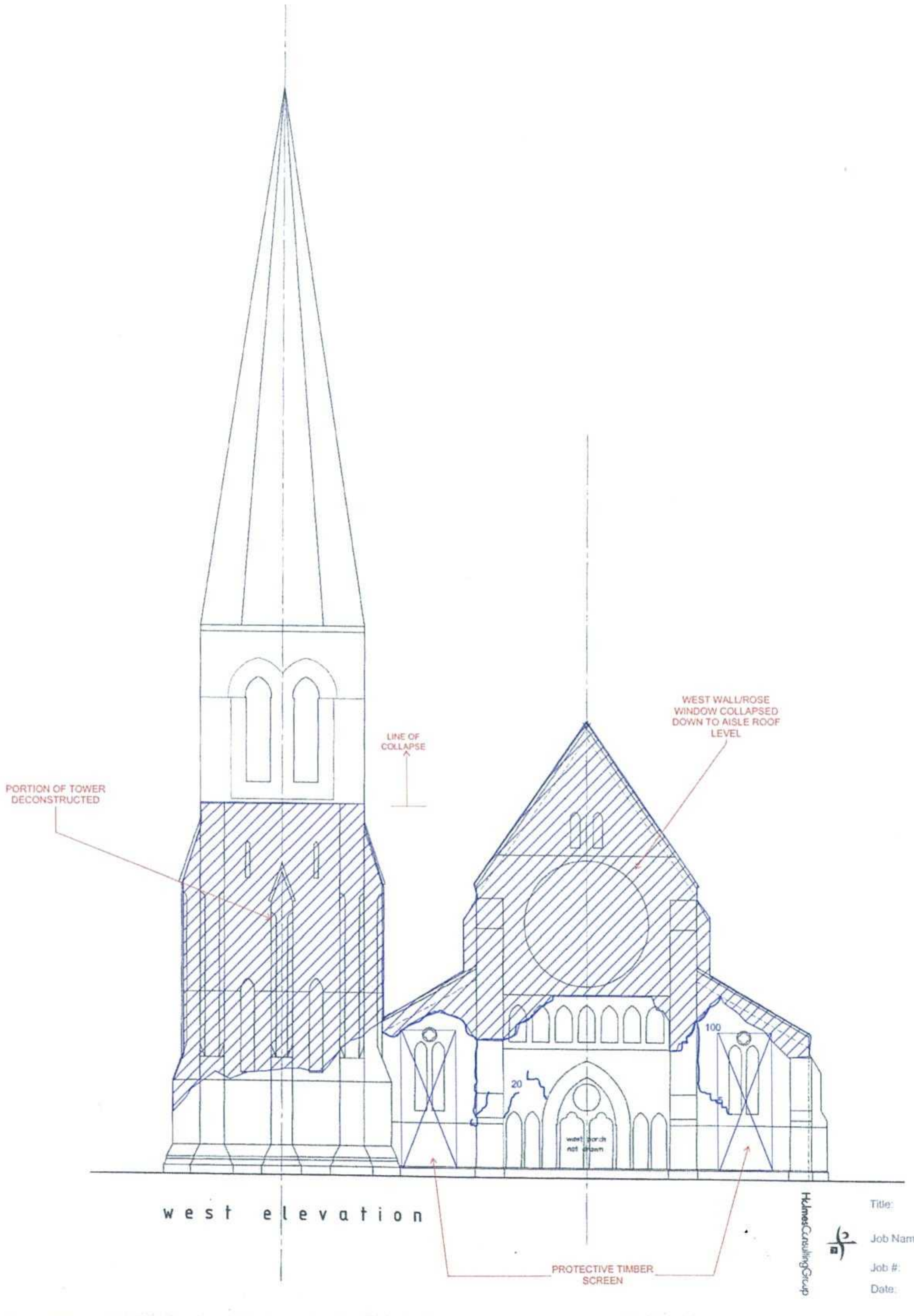
Job Name	Christchurch Cathedral Review
Job #	106324.04 SSK # 001
Date	14/01/2013 Rev 6

north elevation

Title	North Elevation External Damage Review
Job Name	Christchurch Cathedral Review
Job #	106324.04 SSK # 002
Date	14/01/2013 Rev 6



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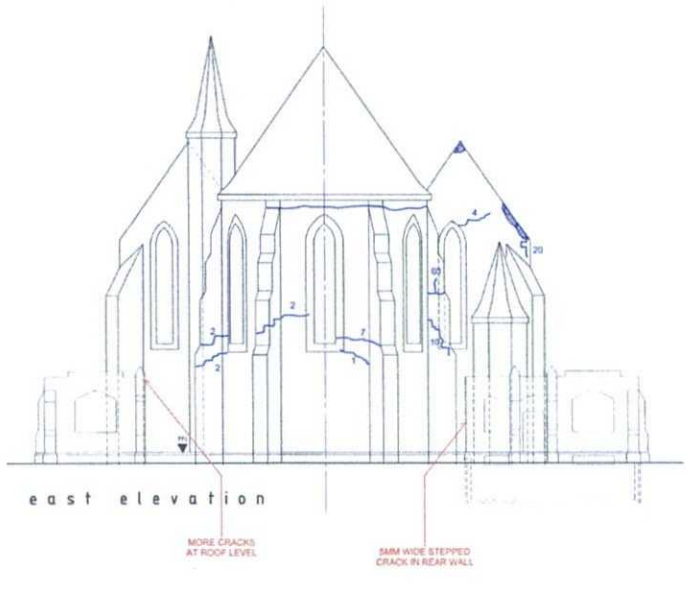
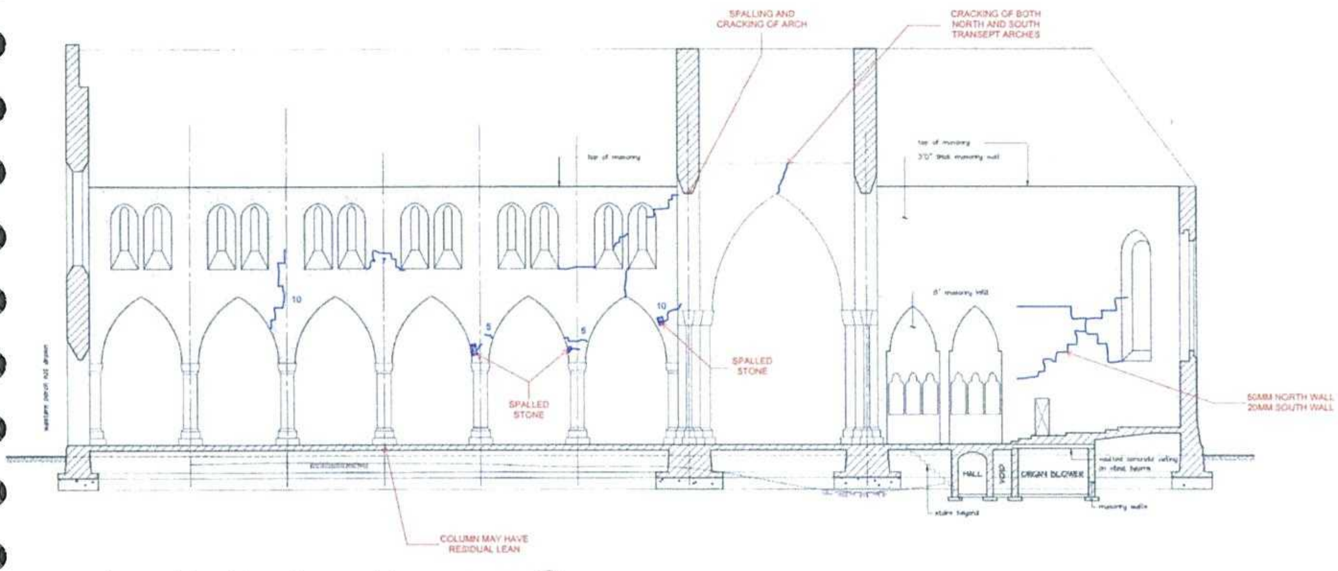
Title:	**West Elevation External Damage Review**
Job Name:	**Christchurch Cathedral Review**
Job #:	**106324.04** SSK #: **003**
Date:	**14/01/2013** Rev: **6**



Title	East Elevation External Damage Review		
Job Name	Christchurch Cathedral Review		
Job #	106324.04	SSK #	004
Date	14/01/2013	Rev	6



longitudinal section nave

Title	Longitudinal Section Nave External Damage Review
Job Name	Christchurch Cathedral Review
Job #	106324.04 SSK # 005
Date	14/01/2013 Rev 6

Holmes Consulting Group

Appendix 3
Indicative costs of engineering options

The indicative costs of reinstatement and replacement are based on 2012 estimates by the quantity surveyors, updated to 2015 by incorporation of an escalation factor.

REINSTATEMENT OPTION

Initial works

1. Tower controlled demolition (partly completed)	$625,000
Sub-Total	**$625,000**

Reinstatement

2. Temporary stabilisation	$9,625,000
3. Separate contracts	$485,000
4. Deconstruction & reconstruction	$54,870,000
Sub-Total	**$64,980,000**

Project costs

5. Temporary storage	$600,000
6. Contingency	$60,000
7. Professional fees	$115,000
8. HPT archaeological recording	$250,000
9. Concept design phase fees to date	$500,000
Sub-Total	**$1,525,000**
TOTAL (excluding escalation & base isolation)	**$67,130,000**
10. Actual escalation from 2012 to 2015	$7,000,000
11. Base isolation	$8,260,000
TOTAL (excluding future escalation)	**$82,390,000**
12. Escalation during design *(Agreed at 12.00% overall for 2 years)*	$10,000,000
Sub-Total	**$92,390,000**
13. Escalation during construction *(Agreed at 28% discounted at 50%)*	$13,000,000
TOTAL	**$105,390,000**

Notes:

Item 2: The initial estimate for temporary stabilisation done in June 2012.

Item 10: The quantity surveyors are agreed that since the estimate was compiled in 2012 inflation within the Christchurch market has equated to approximately 12.00%.

Item 11: It is agreed that a likely construction period would be 5 years and that an appropriate compounded escalation rate over this period would be 28.00%. This is then discounted by 50% (i.e. reduced to 14.00%) since construction starts and is completed within this 5 year period with an anticipated completion date of end of 2022.

All above figures include contingencies, which total $9 million.

REPLACEMENT OPTION (CONTEMPORARY CATHEDRAL)[8]

Initial works

1. Tower controlled demolition (partly completed)	$625,000
2. Removal of stained glass windows	$100,000
3. Organ deconstruction	$240,000
4. HPT & archaeological recording	$250,000
5. Contingencies & fees	$320,000
Sub-Total	**$1,535,000**

Project costs

6. Temporary storage	**$600,000**

Retrieval of artefacts

7. Temporary works	$2,020,000
8. Heritage protection & salvage	$355,000
Sub-Total	**$2,375,000**

Building

9. Tower	$4,000,000
10. In-place deconstruction	$5,845,000
11. Cathedral	$36,685,000
Sub-Total	**$46,530,000**

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[8] Based on a Warren and Mahoney design done in May 2013 (attached).

12. Base isolation		Excluded
13. Escalation (7.5 years total)		**$12,015,000**
	TOTAL	**$63,055,000**
14. Base isolation (included)		**$3,000,000**
	TOTAL	**$66,055,000**

Notes

Item 7: Allows for scaffolding the complete façade and minimal temporary propping.

Item 8: Based on the most elementary and expedient retrieval of artefacts wherever possible.

Item 10: Demolition costs could be higher should the project be subject to delays, especially if associated with lengthy litigation.

Item 12: To provide a higher level of protection to future heritage elements and contents, base isolation may be added. The additional cost may be about $3 million.

Item 13: Based on a completion date of late-2019 and an escalation factor 7.5 years from 2012.

All above figures include contingencies, which total $3 million.

Exclusions

The following items are excluded from both estimates:

- archaeological delays
- operating & maintenance costs
- ESD/Greenstar initiatives
- temporary cathedral
- council utility services upgrades
- disposal of contaminated soil
- title changes & relocation costs
- finance/fundraising costs
- prolonged resource consent costs
- non-competitive tendering
- land costs
- GST.

Timing

Both indicative estimates are based on 2022 and 2019 completion dates respectively. Delays will lead to further escalations and costs.

David Doherr
Barnes Beagley Doherr

Julian Mace
Rawlinsons

12 November 2015