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STRUCTURAL AND CIVIL ENGINEERS

18 July 2012

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CHRISTCHURCH CATHEDRAL
INDEPENDENT PANEL OF STRUCTURAL ENGINEERS REPORT

Dear Marcus

As requested by the Church Property Trustees (CPT), we have reviewed the Independent Panel of Structural Engineers (IPSE) report prepared for the Great Christchurch Buildings Trust, addressing the specific questions that you posed. Please note that this report is brief, given the short time that we have been given to respond. However, given our involvement through the review process, we are very familiar with the IPSE report contents.

This review is based on both the written content of the report and the presentation of the report at the meeting of 9 July.

Summary

In responding to the questions posed by the Great Christchurch Buildings Trust, the IPSE report has generally supported the earlier conclusions reached by Holmes Consulting Group (HCG). The panel has not provided any significant 'game-changers' in its review of the HCG reports, but it has provided amplified detail of a maximum retention option methodology for the temporary works. This follows generally the same sequence proposed already by HCG; and for which a cost estimate was prepared by Church Property Trustee's quantity surveyor as part of the comparative costing exercise completed in February 2012 prior to the decision to deconstruct.

The panel has informally offered an opinion that the maximum retention option could be cost-effective in comparison with deconstruction and rebuilding from sill level, but that has not been tested by a quantity surveyor. Without this, the opinion is questionable, as the shoring system described is mechanically elaborate and a major engineering undertaking in itself, by contrast with conventional construction techniques that could be employed in rebuilding following the deconstruction. However this

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method has the benefit of greater retention of heritage fabric, if the cathedral is to be restored to its original form.

In response to the questions that HCG was requested specifically to address:

1. There have been no new structural engineering options proposed by the panel that have not already been considered by CPT and its consultants.

2. The methodology proposed by the panel cannot practically achieve full protection of workers to the level previously required by CERA, which allowed no use of safe havens.

3. The shoring methodology proposed by the panel may be designed to achieve a high degree of protection of the remaining building during restoration, but at considerable expense. Given the impact of seismic strengthening, only the roof will remain substantially unaltered through the process.

4. Once strengthened, the cathedral can achieve a high degree of seismic protection as previously stated by HCG as well as the panel; but it may never achieve the same level of functional performance as a new cathedral, or a cathedral that encompasses part of the existing fabric and part new design.

These points are all expanded on below.

Engineering Options

You asked us first to give our opinion as to whether the IPSE report had highlighted any new options or provided any new information that may have been missed earlier.

In respect of strengthening measures, the IPSE report itself answers this question, either explicitly stating or implying that it agrees with the overall engineering approaches taken in the consideration of possible options for retention of the Cathedral. In particular we note that we agree entirely with the panel's responses to the eight questions that were posed by the Great Christchurch Buildings Trust, many of which had already been addressed by HCG.

In providing a list of potential strengthening methods, it covers methods and techniques already considered in principle or in detail. It confirms the opinion, already given by HCG, that the building could be restored either in full or in part.

The IPSE report further addressed both deconstruction (DCO) and maximum retention (MRO) methodologies, both of which have been previously considered and addressed in the options decision matrix proposed by HCG in Consultant Advice 025 (January 23, 2012).

The IPSE review has placed considerable emphasis on the maximum retention option, with the inclusion of a reasonably detailed methodology for the shoring of the nave, to a level of detail beyond that reported previously by HCG. However we note that the general approach and sequence of works is very similar to that already outlined by HCG in Consultant Advice 027 (February 9, 2012).

It should be noted that the HCG reports developed each of the considered options to a consistent level, in order for the quantity surveyor to prepare comparative costings. The preparation of detailed methodologies would normally be a joint effort between contractor and engineer, given that the responsibility for site safety generally lies with the contractor.

The IPSE offered an opinion, with no supporting material, that the maximum retention options offered would be more cost-effective than deconstruction and rebuilding, if the cathedral is to be fully reinstated. This is disputed, as discussed in more detail below.

Therefore it can be concluded that there is no new material introduced by the IPSE, in an engineering sense. However it has offered more detail in the methodology of the maximum retention option than HCG (noting that HCG's level of detail was specific to the comparative costing process).

Worker Safety

The safety of demolition workers has been a primary criterion for CERA and CPT in their review of the make-safe options. You have asked us to comment on whether the method proposed by the IPSE is likely to offer a level of protection that CERA may accept.

One of the key considerations in this is whether workers are likely to be exposed for periods outside the shelter of the gantry, noting that CERA have indicated that they will not accept the use of safe havens[1]. This is because of the difficulty in remaining upright and mobile during an event large enough to warrant use of the safe havens, i.e. CERA was concerned that in this scenario the safe havens would be ineffective.

It is our view that although the gantry structure and methodology will be designed to minimise time of exposure, it is practically impossible to avoid workers being exposed outside of the safe haven for at least short times. Although the methodologies and equipment may be designed to control this, the reality is that workers will need to leave

[1] A safe haven is a strong shelter that workers may run into in the event of a significant aftershock, that is intended to provide protection against falling masonry and other hazards. For example, the Urban Search & Rescue team used a large diameter, heavy walled steel tube as a safe haven for rescue teams inside the Cathedral. A stationary 'sentry' sounds the alarm in the event of aftershock, at which time all workers have to make their way as quickly as possible to the safe haven.

the protection of the gantry in order to complete critical work. This will be necessary in order to make connections, place packing, locate shores etc.

In a more general sense, the overall safety of workers is a matter of risk management, that is, there is always implicit risk as absolute safety can never be guaranteed. However the risk may be mitigated in such a way as to reduce it to acceptable levels, in most cases.

In the broader CBD demolition works, it has been generally accepted that a residual structure capacity of 33%NBS is sufficient to allow workers to adopt conventional methods without further protection. Therefore the capacity of the gantry and other protective systems should be at least this much to avoid global collapse, but any protective barriers or screens would need to allow for the total weight of material that may fall, as individual masonry elements will not be secured by the temporary works.

In this case, risk management assumes a greater significance, as increasing levels of protection for workers will generally only be achieved by more elaborate and (probably) expensive temporary works, methodologies and equipment. It is noted that there was discussion in the IPSE report and presentation of use of robotics, hydraulics and self-tracking systems. These are definitely viable systems, but will come at considerable cost.

The development of these systems will be time consuming and expensive, noting that there are some extreme space and geometry constraints with the steps up into the transept coinciding with the lower stone arches and higher roof beyond. A system that can work through the shored nave and into this space will be a very impressive piece of mechanical engineering, even beyond the structural work on the building itself.

HCG does not agree that the cost of the temporary shoring and protection will be no greater for the retention option than it would for rebuilding, as stated by the IPSE:

- Firstly, when rebuilding, the strength of the structure can be added progressively as the structure is built, and therefore the shoring can be considerably lighter.

- Secondly, in the rebuilding process, conventional lifting and erection techniques can be used, so there is less elaboration in the system (such as the hydraulics and self-tracking systems noted above).

- Thirdly, as the stone elements will be built into the structure, there is no need for the same level of protection against falling hazards, beyond that which would be conventionally employed on building sites.

Conversely, a statement has apparently been made that the DCO methodology prepared by CPT's preferred contractor and submitted to CERA may present more risk

to the workers. This is strongly disputed. Workers engaged in the removal of masonry elements will always be working from a swinging stage above the masonry, and hence in the event of earthquake will be above any falling masonry and may be swung away by the crane operator. The methodology will be reviewed as work proceeds, and may be varied to include more mechanical demolition if necessary in order to ensure safety, at the possible cost of greater damage to the structure and remaining contents.

In summary, the maximum retention option offered by the IPSE does not offer an equivalent level of worker safety, and so a greater level of risk would have to be accepted. This may be reduced, but not entirely eliminated, by increasing complexity of mechanical systems, with commensurate cost increase.

Temporary Building Protection

You have asked us to consider the degree of protection offered by the temporary works against earthquake.

The temporary works can be designed for greater levels of protection if required, but with consequent cost impact. The cost impact is never linear, that is, the level of protection offered does not increase directly in proportion to cost. It is often possible to optimise a particular configuration of structure to achieve the best protection available from that configuration, but achieving a greater level again may require a completely different method, with a disproportionate increase in cost. No optimisation is yet possible at the current level of detail of either the IPSE proposal or any proposal considered by HCG.

Consideration of costs may be balanced against consideration of what can be saved using the IPSE methodology, in comparison with a rebuild option. The main elements being saved by the MRO are the roof and clerestory. However, the strengthening solution for the clerestory is most likely to involve removal and refixing of at least the inner ashlar stone facing (given that it is not bonded to the weakly cemented rubble infill), in conjunction with the strengthening of the clerestory walls, probably by partial replacement of the rubble infill with reinforced concrete (refer figure 1 below for a diagrammatic explanation of the wall construction, which illustrates the likely location of the reinforced concrete).

Similarly it is likely that the south and north side aisle walls will be partially dismantled, again by removal of the ashlar and replacement of the rubble infill with reinforced concrete. Given the condition of these walls, it is still our assumption that these walls will require complete re-construction above the sill level, both to realign the stone and to restore the masonry bond. It is important to note that the variable nature of the rubble infill in particular makes it impossible to determine a single consistent approach. It is likely that the end solution would be a combination of approaches in order to manage this, determined as work proceeds and actual conditions can be established.

Hence, the roof is the principle element that is retained intact throughout this process, as almost all walls will require a degree of deconstruction in order to complete seismic strengthening.

The strengthening operations described above will place considerable demand on the temporary support structure, which will need to have sufficient capacity to provide stable support to the retained stone elements while the walls are strengthened. The demand may be controlled by staging the works such that there are only limited open work faces in need of stabilisation at any one time. However, as noted in the discussion on worker safety, the cost of this is considerably greater than the cost of the temporary works associated with rebuilding, should CPT take that future option.

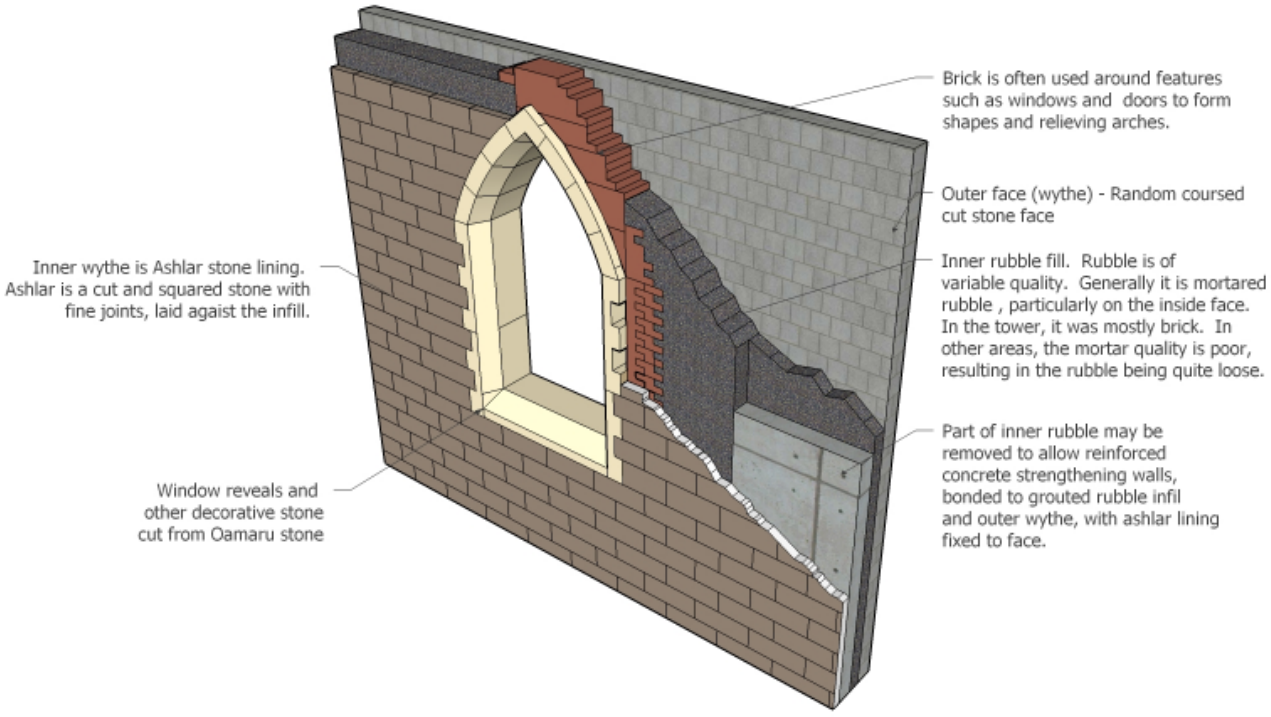

Figure 1: Typical Cathedral Wall construction

A further consideration may be the time of exposure of the structure. While a gantry structure as proposed may have sufficient capacity to be considered safe enough to work in, it will not achieve the full protection that is delivered by strengthening of the structure. It is unlikely also that the strengthening programme will be any quicker to

achieve the final outcome. Therefore the risk of damage to the building itself in that time is greater than for the DCO, acknowledging that it will not be the same building.

We strongly disagree with the opinion expressed by Adam Thornton of the IPSE, that the south and north walls may be repaired insitu using techniques such as sawcutting and jacking:

- Firstly, the extent of movement is such that it is likely that the rubble infill has dislodged internally, preventing the stone being pushed back into position, or alternatively, resulting in increased damage to the masonry if it is simply forced into position.

- Secondly, with the dimensions of the masonry elements, it will not be practical in this way to restore enough of the mortar bond.

- Thirdly, damage to the masonry units has progressed to such an extent that many of the existing masonry elements will need to be replaced (due to excessive spalling and cracking of the masonry).

In conclusion, there is risk of further earthquake damage to the structure with the maximum retention option, which again may be reduced by increasing the capacity of the shoring system. The system must in any case be capable of providing considerable out-of-plane support to the masonry walls, as sections are progressively partially deconstructed and rebuilt during the strengthening process.

Finished Building Capacity

Finally, you asked us to comment on the final outcome of the work in terms of the protection offered to the users and the fabric of the building itself.

In considering this we need to restate what both HCG and the IPSE have already agreed – that it is possible to achieve a high level of seismic protection, well in excess of the minimum that the Building Act requires. This may be accomplished by either retention with progressive strengthening, or by rebuilding. However, it must also be stated that a strengthened structure will almost certainly never be able to achieve the same level of protection as a new structure, as there are inevitably compromises to work with the existing structure.

The corollary to this is that only the strengthened structure is original – a rebuilt structure is a replica and not therefore of the same heritage value. However, as a new structure must be fully code compliant in every respect, it is likely to have greater reserve capacity and ductility than a retained and strengthened structure. It is also debateable from a pure conservation perspective, as to how much of the strengthened

structure is still of the highest conservation value, considering the strengthening process described above.

These factors may be overcome to a degree by consideration of the techniques to be used. A combination of superstructure strengthening and base isolation may be possible, to achieve a level of protection that will adequately compensate for any compromises in the retention of existing fabric. However the installation of the base isolation system is an operation with some increased risk, as the existing foundations will need to be progressively undermined for the installation of the bearings. It is unlikely that the tiled floor will survive this completely intact, but its current condition is not likely to be good, so this may not be a significant issue.

In conclusion, the strengthening of the building following the maximum retention option will require considerably more effort and cost to achieve the same level of protection that a rebuilt structure could.

And Finally

It has always been our position to provide sufficient information for Church Property Trustees to make a very difficult decision. It is our contention that this decision cannot be made solely on engineering grounds, and nor has it been. That other groups have been compelled to suggest otherwise has been disappointing, and detracts from the simple principle of ownership by which a building owner has a right to consider a wide range of criteria in making such decisions. As much as we regret the deconstruction of the cathedral, we will continue to provide the best advice that we are able as the Trustees continue with their task.

Yours sincerely

John Hare

PRINCIPAL