STRUCTURAL REPORT

MASTERTON DISTRICT COUNCIL MUNICIPAL BUILDING & TOWN HALL

Circa 1930s

Circa 1950s

Circa 2010s

LGE Consulting
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Structural Report on the Masterton Town Hall and Masterton Municipal Building

Prepared for

Masterton District Council

Date: 27th September 2016

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Revision: A – Draft for comment

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Structural & Civil Engineers

Executive Summary

- The Town Hall and Municipal Building had a detailed seismic assessment completed in 2004 by Spencer Holmes. This report rated the buildings at 40%NBS based on a soil type of 'C'.
- The calculations completed for this report confirm the results of the Spencer Holmes review. Recently provided Geotechnical information for the Wairarapa region indicates that the soil type is 'D'. This means the Spencer Holmes result of 40%NBS becomes a result of 30%NBS for the now confirmed Wairarapa soil types.
- There are three structures on the site, with the focus of this report the 1915 Hall and Municipal building (ie the civil defence structure is not included in this report).
- A structural review has been completed to determine what is required to improve the seismic compliance of the Hall and Municipal Building.
- The works required to improve the Hall are substantial, and appear to be of a scope similar to constructing a new Hall structure.
- The works required to improve the seismic performance of the Municipal building to a minimum of 80%NBS are as shown in the attached plans S1-S24 tilted 'Seismic Improvement Scheme, Masterton Municipal Building'. The street façade will be retained and re-supported. The scheme will require demolition of portions of brick walls, and the complete stripping of internal finishes to allow for construction.
- The final structural and architectural requirements of the project will be dictated by the future desired use of the site.

Contents

1. Overview of the Site

The site is home to three structures in total, as shown in the aerial photo below. This report focuses on the original Municipal and Town Hall buildings, outlined in red and hatched below.

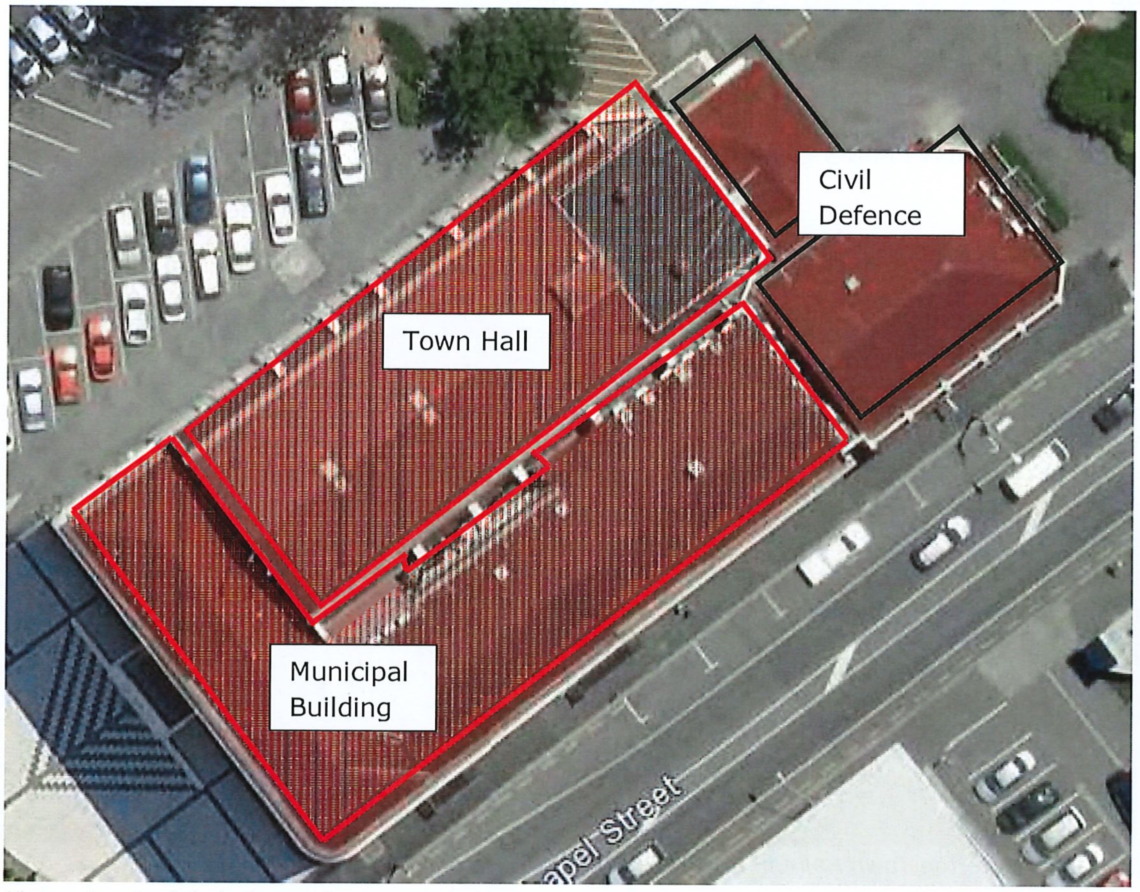

Figure 1 – Aerial photograph

The Civil Defence buildings were constructed in 1984 as an extension to the Municipal buildings.

2. History of the Structure

The Town Hall and Municipal building were constructed in 1915. The structure was originally of unreinforced masonry (URM) construction, typical of the era. There have been several additions to the original structure, namely the civil defence building and a rear extension to the main hall. This report focuses on the Hall and Municipal building, indicated in the aerial photograph above.

Though there is some connectivity between the Town Hall and Municipal building, they are in essence two structures. As such, each structure is discussed individually.

2.1 Original Construction

2.1.1 Masterton Town Hall

The Masterton Town Hall was originally an unreinforced masonry (URM) structure. The hall was formed with timber trusses spanning between the external URM side walls. The side walls were 20' (6.1m) high and were typical for the era, with 9" (230mm) brick structural walls and a 4½" (115mm) brick veneer separated by a 2" (50mm) cavity. The external side wall had 14" brick piers at each truss location.

At the front of the Town Hall building there is a two storey section, housing the entrance on the ground floor, and a cloak room and lounge above.

Figure 2 – Masterton Town Hall Circa 1920s

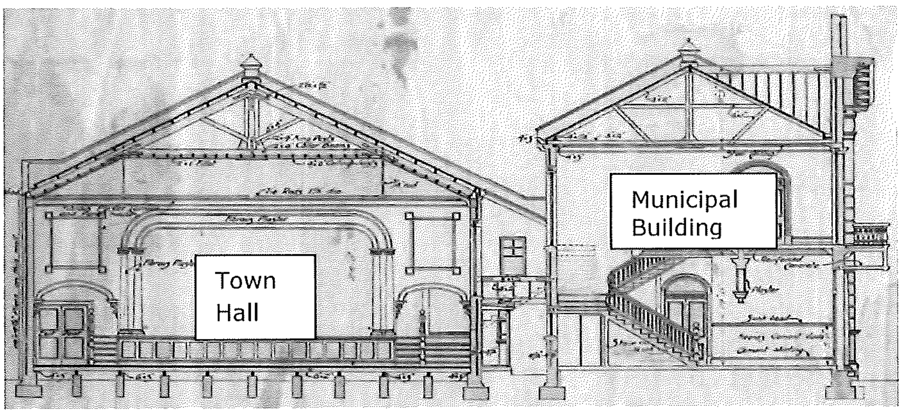

Figure 3 – Original Section through hall and municipal building

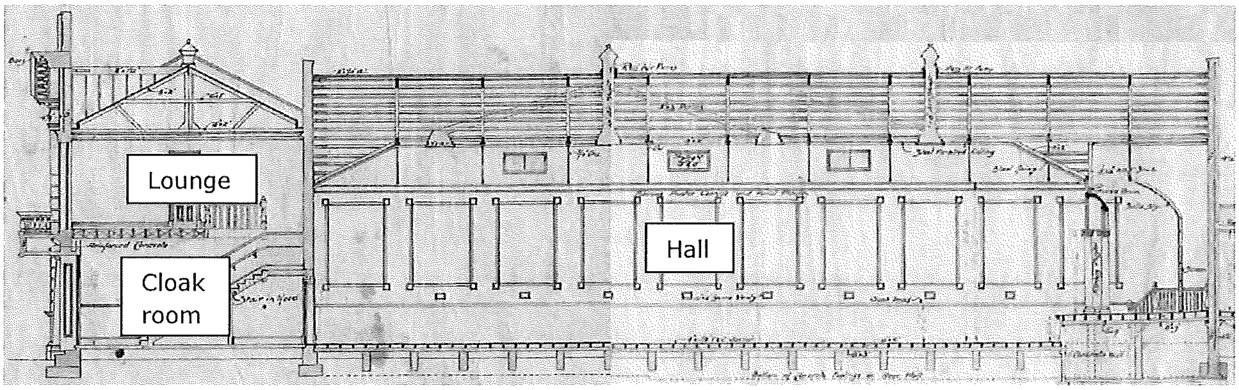

Figure 4 – Original Section through Town Hall

2.1.2 Masterton Municipal Building

The Municipal Building was also constructed of unreinforced masonry (URM) walls. It is a two storey building, with a ground floor stud height of 14′ (4.3m) and a first floor stud height of 12′ (3.6m).

The ground floor has an entry section with concrete slab on grade, however the majority of the floor structure is timber. The first floor is formed by timber joists spanning between steel beams which are in turn supported on the brick walls.

The original floor plan for the building showed multiple internal brick walls on both the ground floor and first floor.

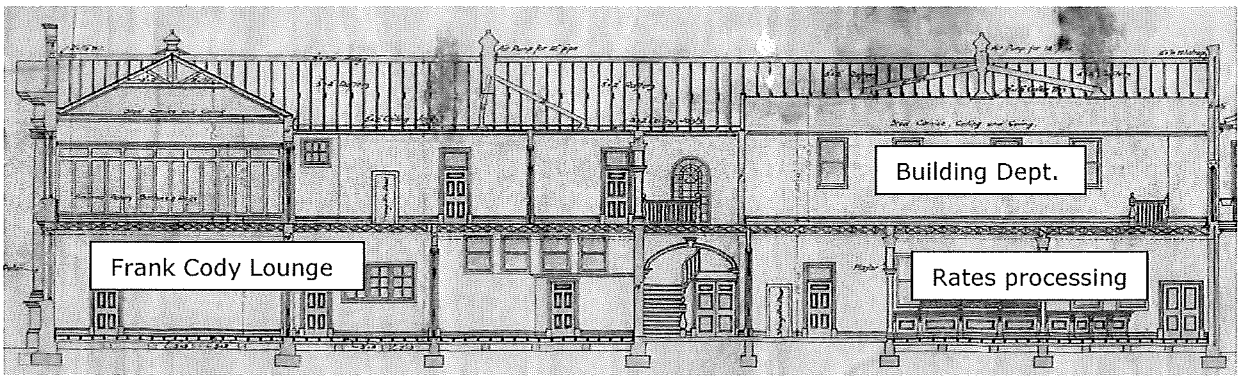

Figure 5 – Original Section through Municipal building

The Municipal building was originally separate from the Hall structure, with an open void between the buildings.

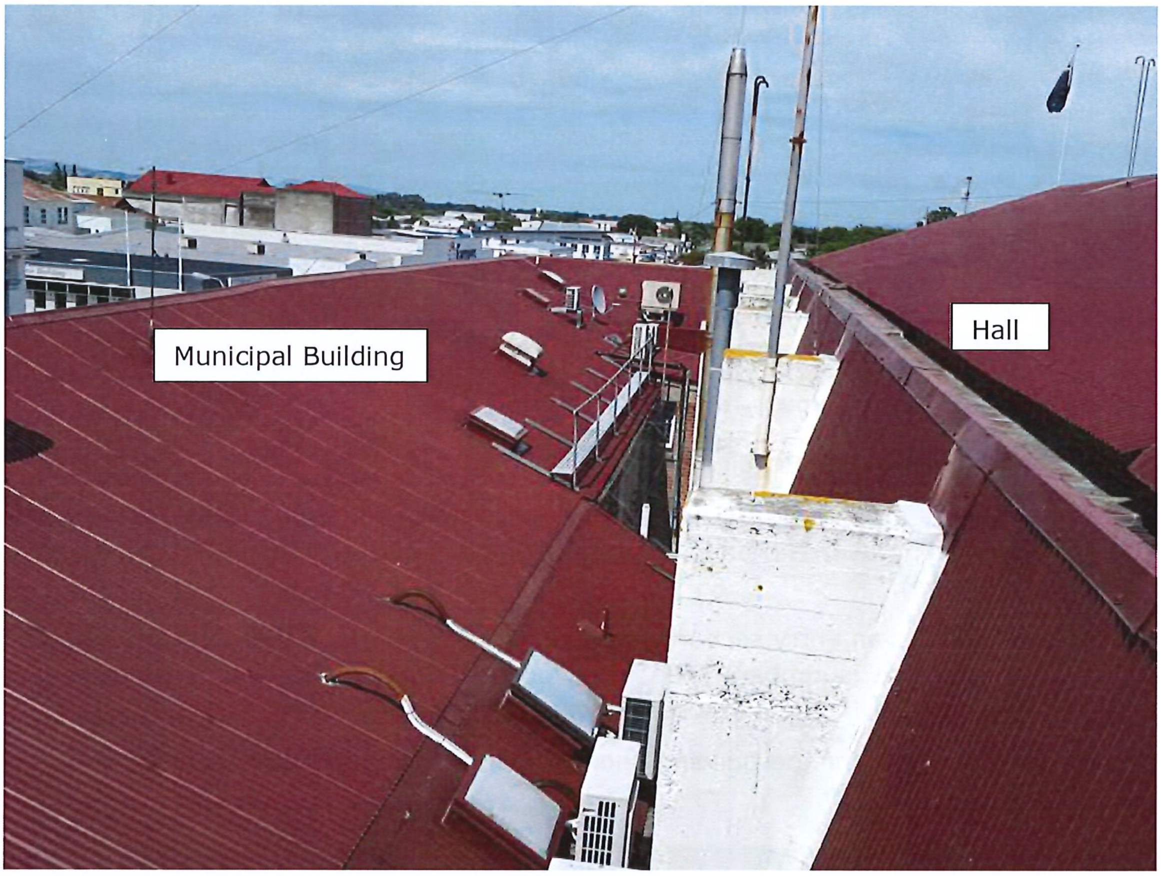

Figure 6 – Photo of roof – note space between the Hall & Municipal Building

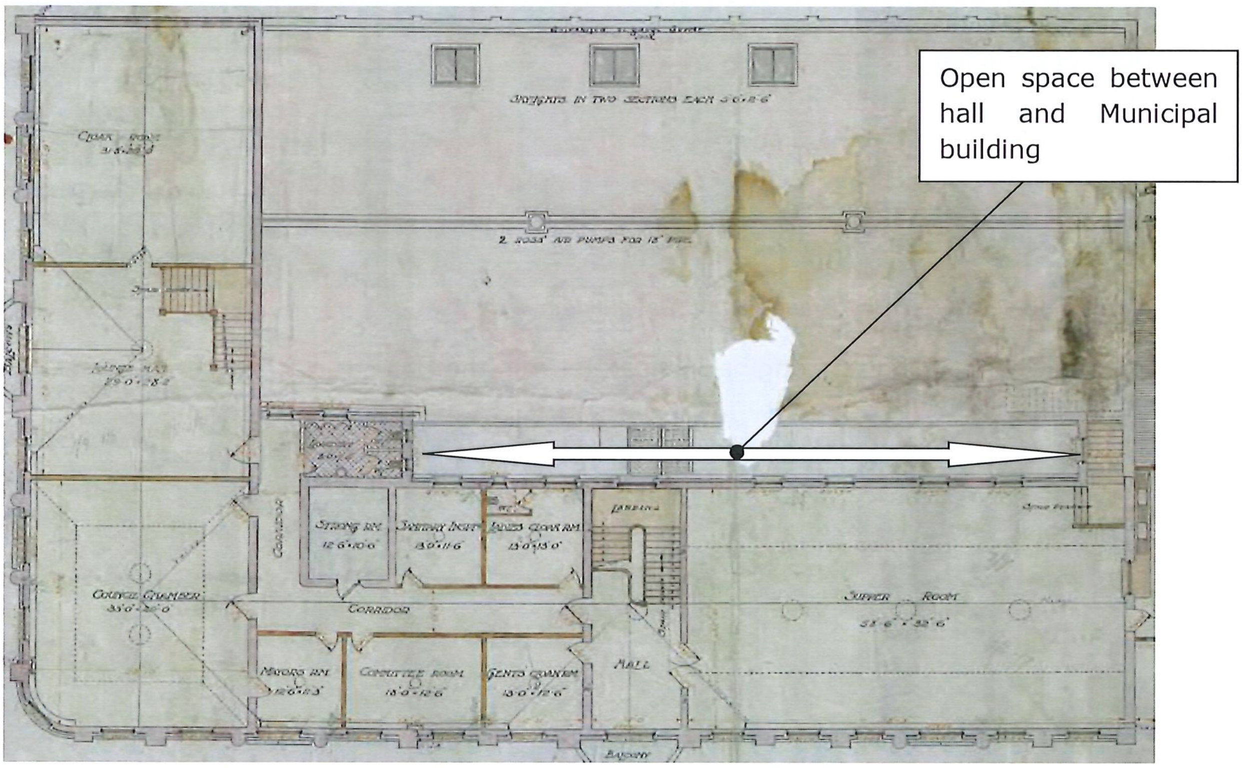

Figure 6 – Original 1915 First Floor Plan – note space between hall and offices

2.2 1942 Wairarapa Earthquakes

In 1942, the Wairarapa was subject to two earthquakes. The earthquakes are estimated to have provided moderate shaking levels compared to current design standards, however they caused a reasonable amount of local damage.

The Municipal building suffered some damage at the time, with a photograph available of the Chapel St frontage. This photograph shows damage to the parapets on Chapel St, with brick sections falling to the street.

Figure 7 – Post 1942 earthquake showing minor damage.

The Masterton Borough Surveyors report on the 1942 earthquake damage noted the following in regards to this building:

"This is a very large building with exceptionally massive brick frontages to Chapel and Perry Streets. There are brick partition walls in the office portion, but the continuity of the structure is badly broken by several large chambers. Although it suffered little damage in this earthquake, it can only be classed as a bad public risk. The extremely heavy street parapets, together with ornamental cornices etc should be taken down immediately, and the earliest opportunity seized of equipping the building with a carefully designed system of reinforced concrete framing."

2.3 1954 Strengthening / Refurbishment / Extensions

In response to the above, the building was subjected to substantial works in the 1950s.

2.3.1 Masterton Town Hall

The Town Hall had a major alteration as part of these works. The entire roof was lifted by approximately 5.2m. This was achieved by placing reinforced concrete components through the original brick structure. New concrete frames were constructed across the width of the hall at regular centres. Around the external perimeter of the hall a new concrete parapet was constructed, supported by the original URM walls.

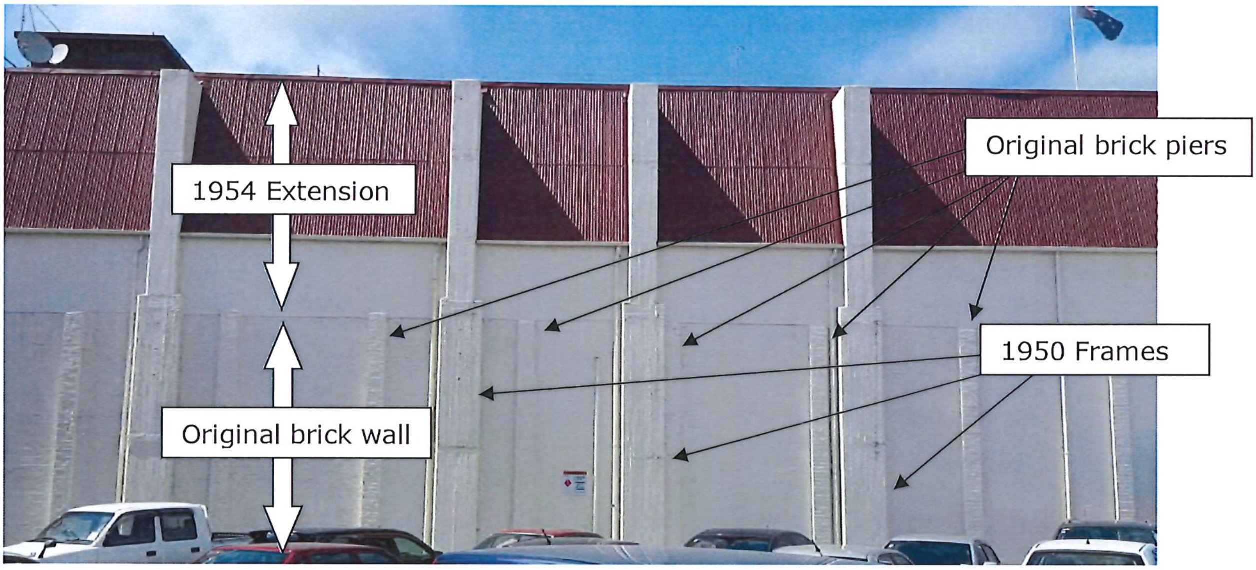

Figure 8 – Side wall of Hall – new frames marked, original brick side wall visible

The frames are reasonably well detailed for their era, however they are lightly reinforced.

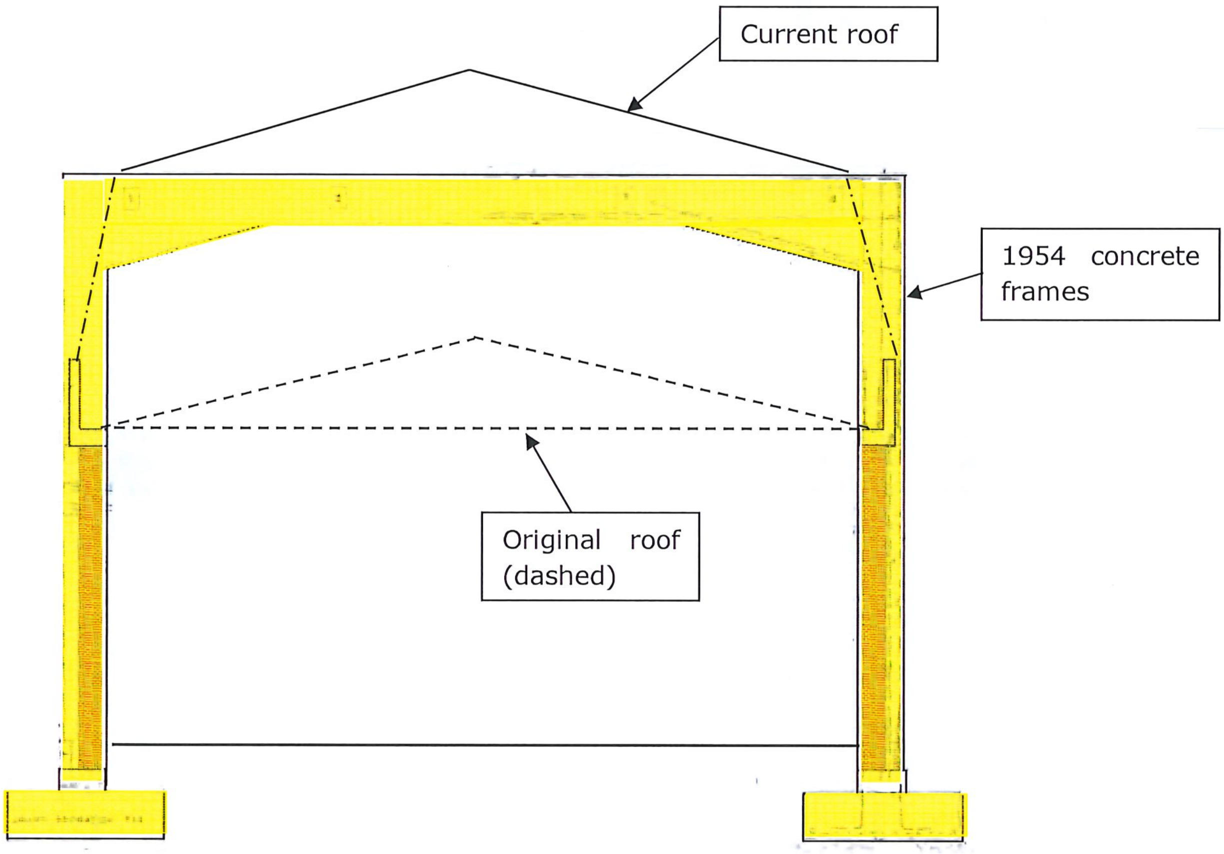

Figure 9 – Hall Transverse Frames

The rear of the Town Hall was extended to form the current stage area. This extension was formed with reinforced concrete walls. The quality of the construction is typical of the era, with areas on "boney" concrete visible and exposed sections of reinforcing steel.

Figure 10 – Rear of Hall showing reinforced concrete extension

Figure 11 – View of hall extension "boney" concrete – poorly vibrated concrete resulting in exposed aggregate.

New elevated seating was erected which is supported on a fabricated steel beam spanning across the hall. A new projector room was also constructed. This projector room is formed with reinforced concrete walls, floor and roof. It is supported at the rear via the original brick wall, and the front by two slender reinforced concrete columns

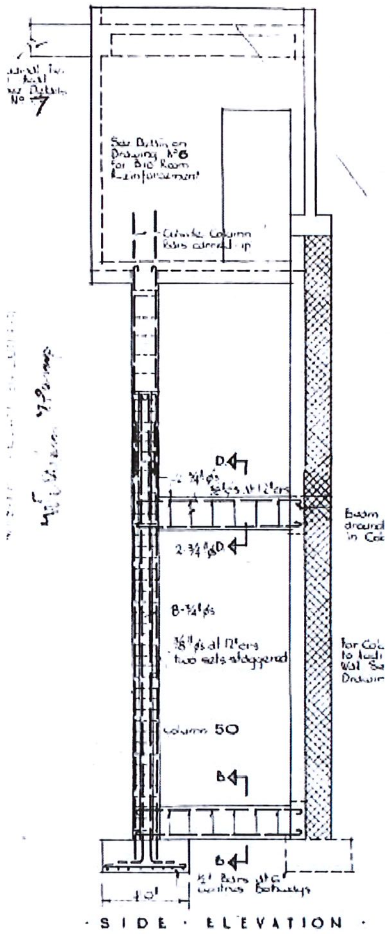

Figure 12a – Elevation of the projector room, showing the heavy concrete 'box' supported on the URM wall at the rear and on concrete columns at the front.

Figure 12b – Projector room

Figure 12c – Poor construction details evident in this beam to column joint

2.3.2 Masterton Municipal Building

To address the seismic risk presented by the Chapel and Perry Street URM frontages, a new reinforced concrete façade was constructed.

The original building façade consisted of a 9" thick URM wall with a brick veneer on a 2" cavity. During these works, the brick veneer was removed, and a 'skin' of reinforced concrete was wrapped around the building façade. The façade concrete is doubly reinforced and reasonably well detailed for its era.

On the inside of the building structural steel elements were placed hard against the brick wall. Steel rods were used to sandwich the original brick between the new reinforced concrete and the new steel members.

Though the façade (shown in yellow in figure 13) had a complete and substantial reinforced concrete 'skin' wrapped around it, the rear wall line (shown in red in figure 13) of the Municipal office building was left largely as original, (ie 9" thick brick with veneer). The rear wall lines had reinforced concrete bands installed in and around the brick work. The bands do not form a complete frame system, and are offset where required to accommodate the original structure. There is some poor quality construction in these concrete components.

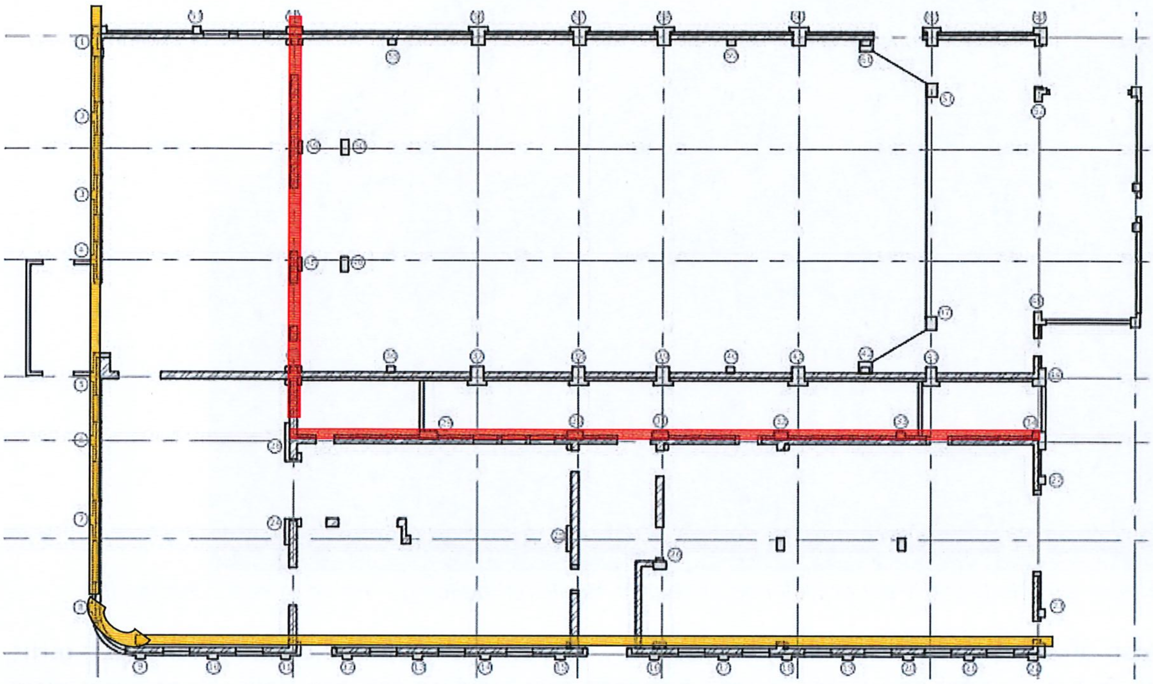

Figure 13 – Ground floor plan. Façade concrete highlighted yellow. Rear wall line shown in red.

This means that the lateral load resisting system along these external wall lines is still original 9" brick wall.

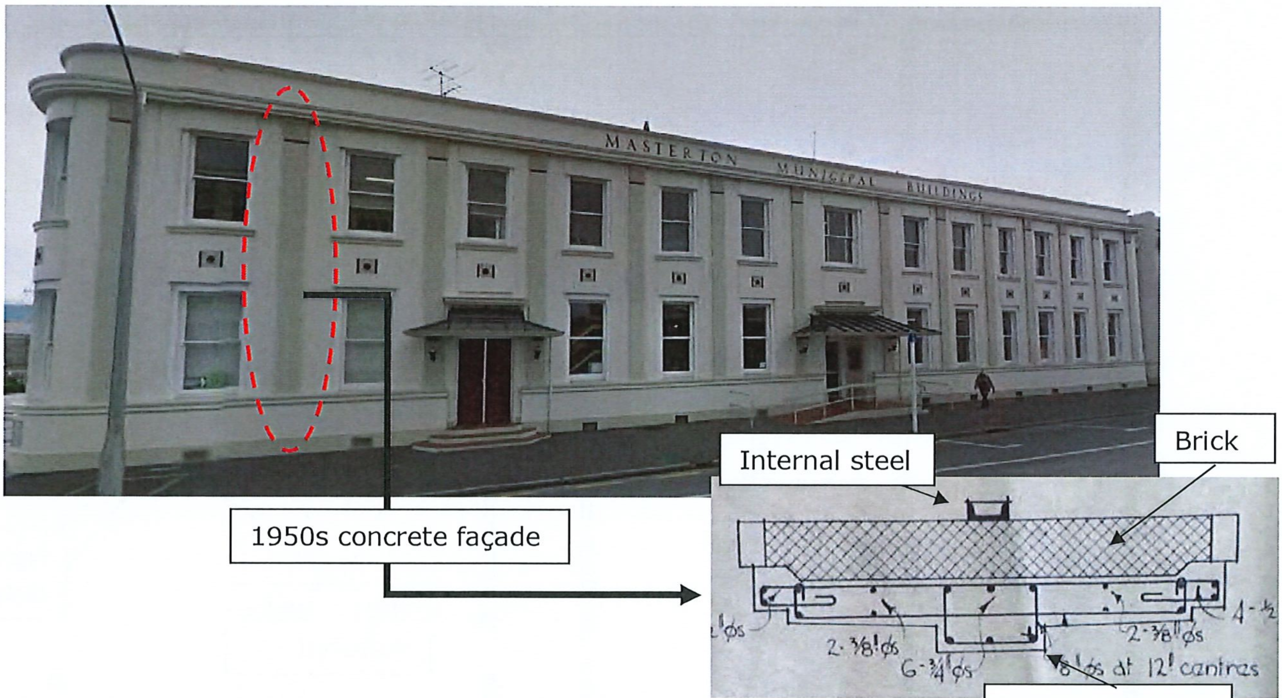

Figure 14 – Detail of 1950s concrete 'skin' wrapped around original brick

Figure 15 – External view of wall line at rear of Municipal building (shown in red in figure 13)

Also during the 1950s strengthening work, on the first floor of the Municipal building the roofing was extended over the void between this building and the Hall. Floor joists were placed across the void to form additional office floor space. The first floor brick wall was entirely removed from this section of the building.

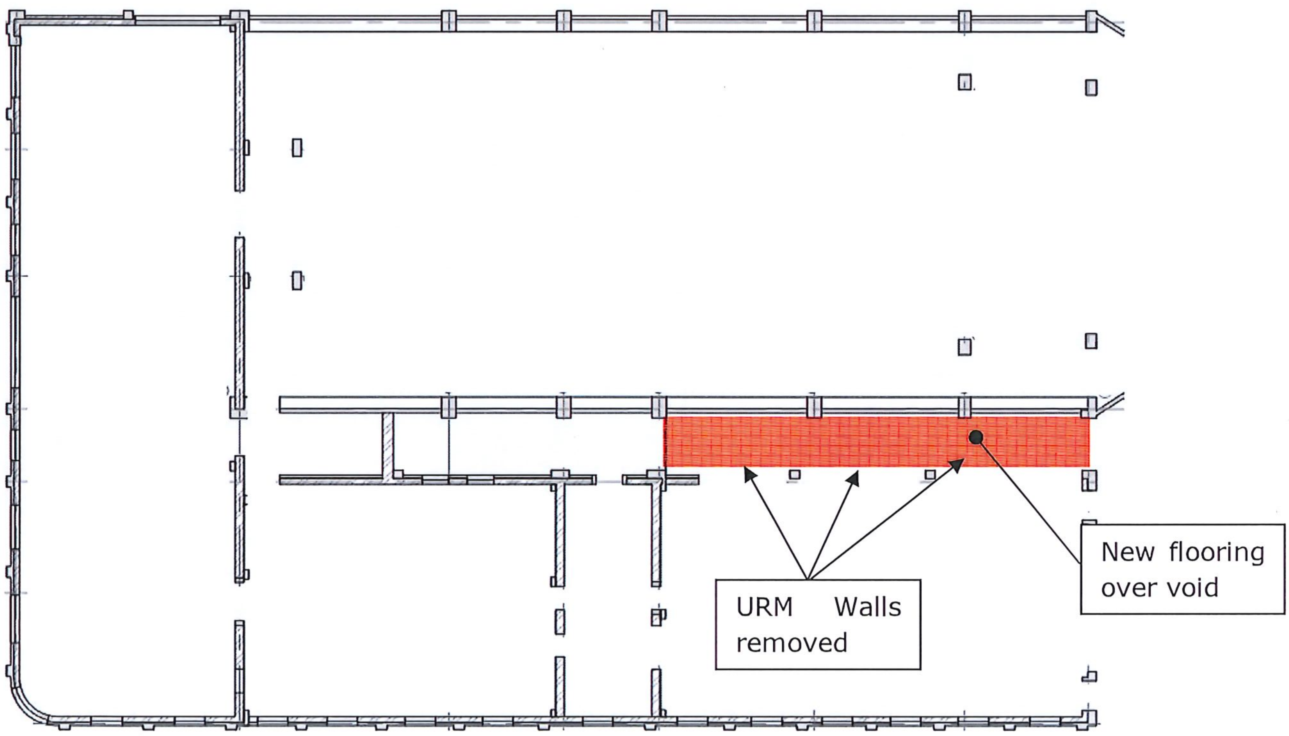

Figure 16 – First Floor Plan after 1950s work – note walls removed

The Hall and the Municipal building are two different structures, ie one has very high concrete frames in the transverse direction (see figure9), while the other is two storied with in-plane URM walls. This means the buildings are likely to move out-of-sync relative to each other during an earthquake. The new flooring spans the void between the two buildings, and is supported on a stringer attached to the Hall. This means there is a potential loss of gravity support to this section of flooring during a seismic event.

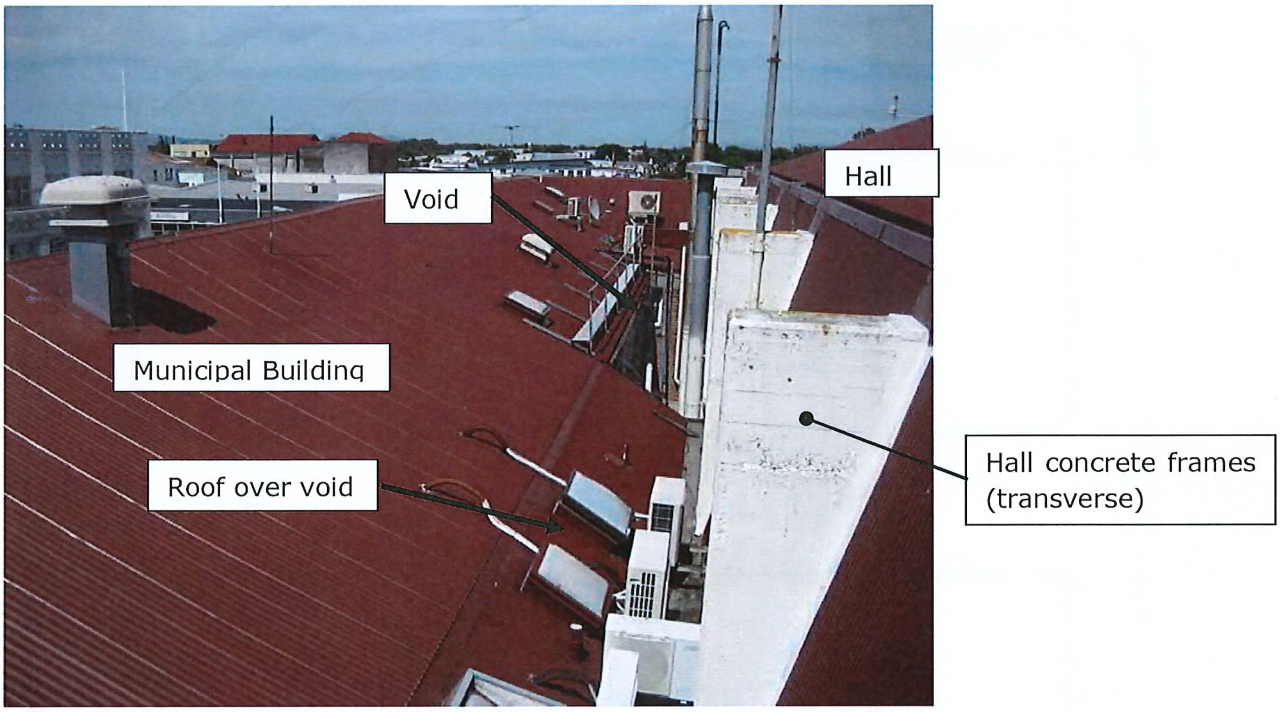

Figure 17 – Roof Plan – note new roof bridging the gap between the Hall and Municipal Building

2.4 Alterations between 1954 to Present Day

2.4.1 Masterton Town Hall

The Town Hall building appears to be as per the 1950 structural plans. An alteration to the staging area was recently completed, with minor structural works.

The ground floor foyer area of the front two storey hall area has been subject to alterations. These involved removing internal URM walls on the ground floor.

2.4.2 Masterton Municipal Building

The Municipal Building has also had ongoing alterations, particularly to the ground floor. Internal sections of URM wall have been removed as required to accommodate refurbishments.

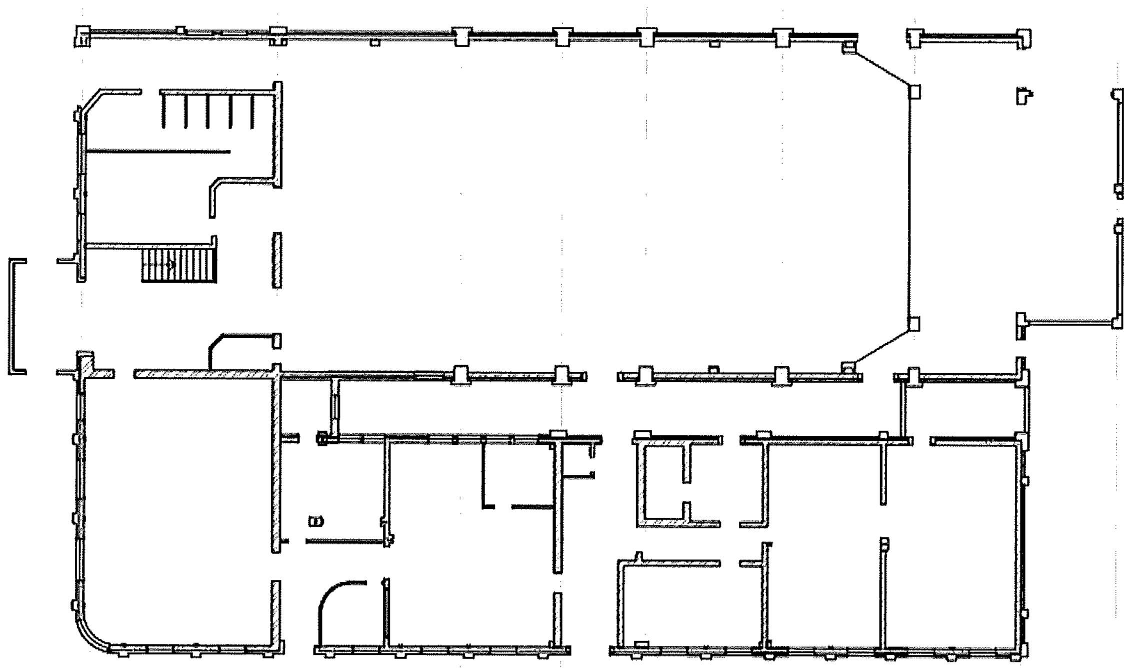

Figure 17a - Circa 1920s floor plan

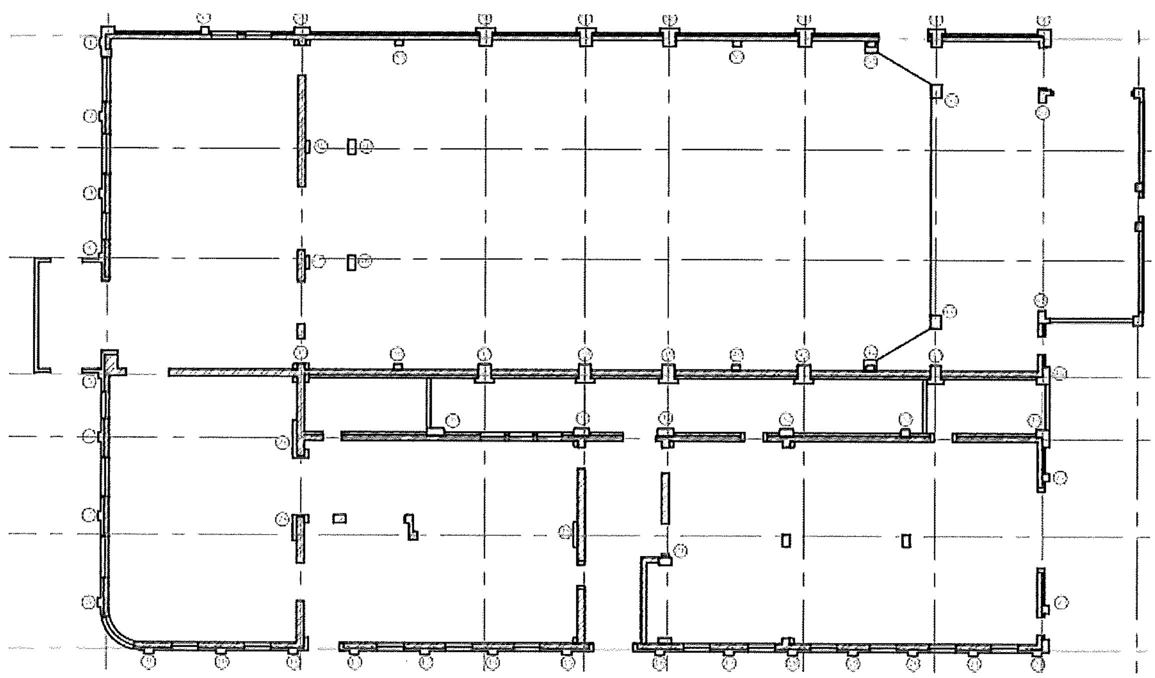

Figure 17b - Current floor plan – note internal walls removed

3. Previous Structural Reviews Completed

In 2007, Spencer Holmes completed a report on the Town Hall and Municipal buildings. The assessment completed at this time appears to have been an overview of specific structural components in the building. The report notes that the site was assessed as a sub-soil class 'C' soil.

In 2008, GNS Science provided a draft sub-soil map for the greater Wellington region. This map designates the Masterton urban area as sub-soil class 'D'.

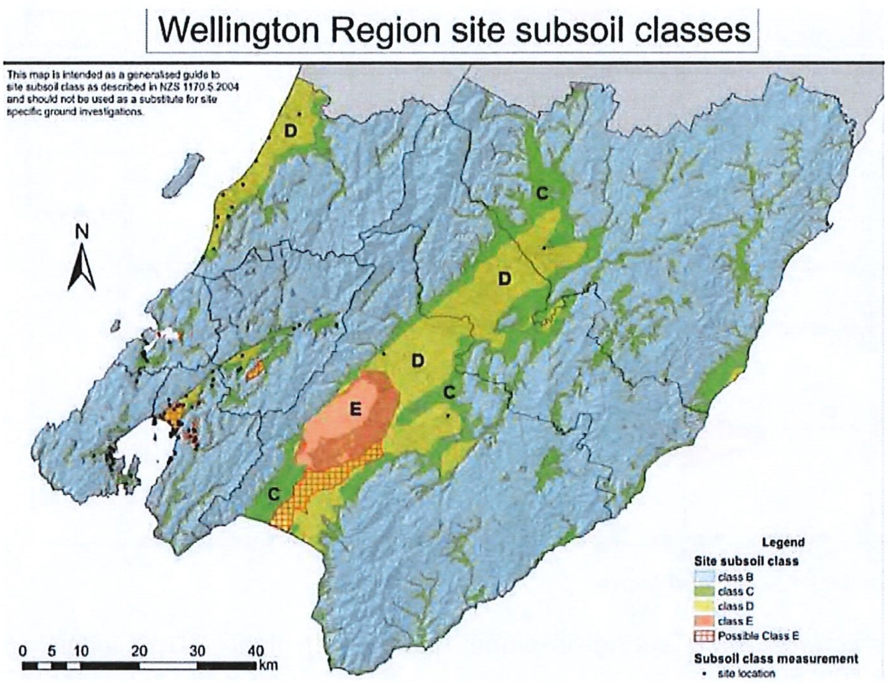

Figure 18 – DRAFT GNS sub-soil map for the Wairarapa

For seismic design, the site sub-soil class directly influences the magnitude of forces a building must be designed for. A structure being designed on a site with a sub-soil class of 'D' must be designed for approximately 30% greater loads than the same structure on a site with a sub-soil class of 'C'.

The Spencer Holmes report notes that with a soil type of 'C', the building achieves 40% New Building Standard (NBS). Modifying this figure to allow for the load increase due to a soil type 'D' would provide a compliance level of approximately 30%NBS.

4. Structural Load Resisting System

The Loadings Code AS/NZS1170 tells an Engineer what loads a building must be designed for based on the Importance Level of a building. Importance level is determined by the use of the building. For example, a hospital is considered Importance Level 4, while a farm shed is Importance Level 1. The Hall has been assessed as Importance Level 3 as it contains an area where over 300 people can congregate. The Municipal Building has been assessed as Importance Level 2.

A structure must be designed to resist lateral (sideways) loads in both orthogonal directions, ie 'across' the building, and 'along' the building. The capacity of each direction needs to be independently assessed.

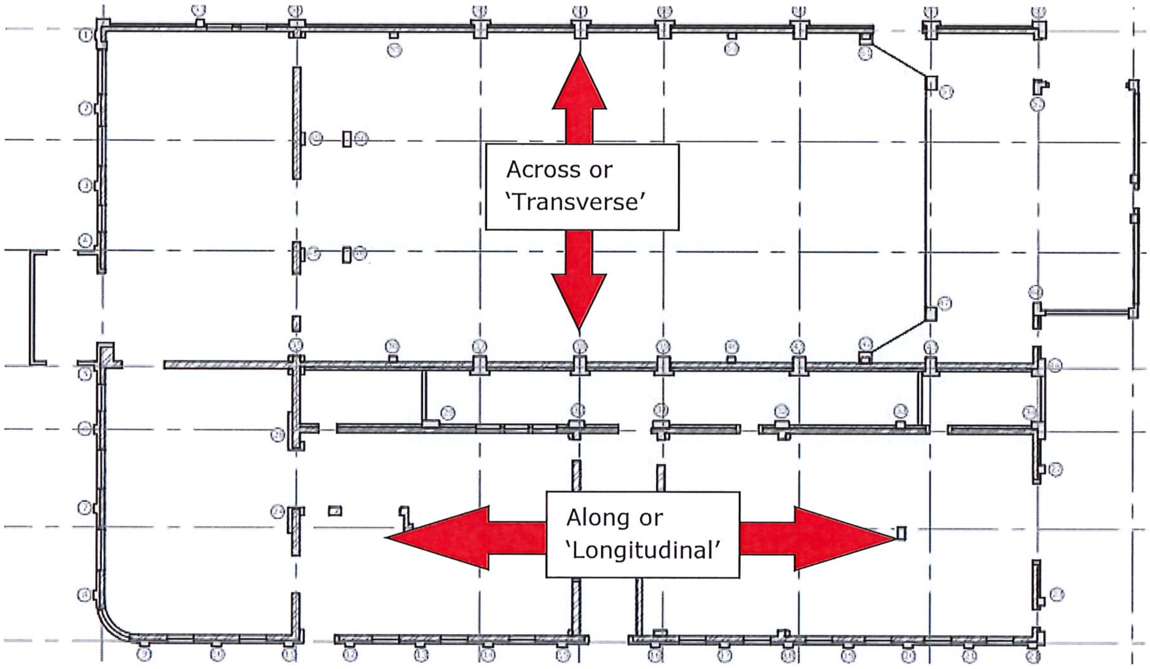

Figure 19 – Floor Plan showing 'along' and 'across'.

This report will also reference walls acting 'in-plane' and 'out-of-plane'. The following figure illustrates these concepts.

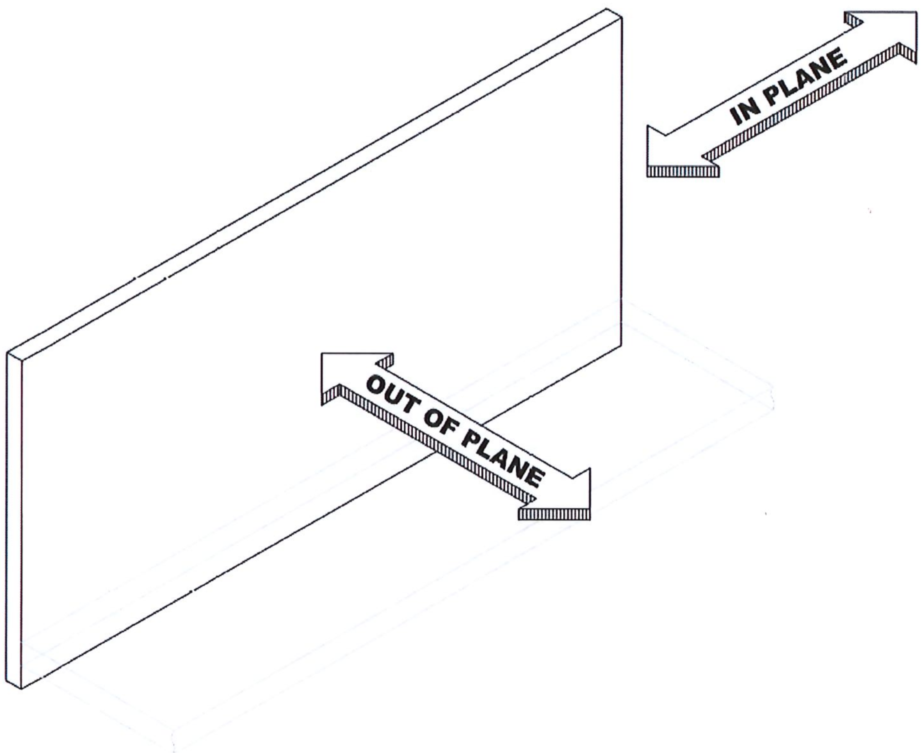

Figure 20 – Schematic Illustrating In-Plane vs Out-Of-Plane.

4.1.1 Town Hall

The Town Hall resists lateral loads in the transverse direction via the 1950s reinforced concrete frames. The frames are tall, with light levels of reinforcing.

In the longitudinal direction the seismic loads are resisted via the original brick walls acting in-plane. Above the brick walls the reinforced concrete frames will resist loads by bending about their weak axis.

4.1.2 Municipal / Office Building

The municipal / office building lateral loads are resisted by the URM wall sections acting in-plane. The first floor and roof level diaphragms support out-of-plane elements and transfer loads to the in-plane walls.

5. Assessment of Existing Structure

We have assessed the building in accordance with the NZSEE "Guidelines for Assessment and improvement of the Structural Performance of Buildings in Earthquakes". The seismic demand has been calculated using the New Zealand design standard AS/NZS 1170.

The assessment has been completed based on a two-dimensional analysis using the structural analysis program Microstran.

Material properties used were as follows;

- Concrete strength – 25MPa
- Reinforcing Steel grade – 300MPa

5.1 Town Hall

5.1.1 Transverse Direction

The capacity of the Town Hall frames in the transverse direction has been reviewed. The ductility of the concrete frames was assessed using Response2000, adopting a maximum concrete strain of 0.04. This provided an available section ductility of 2. The mechanism for these frames is yielding in the columns.

The frames were also limited by the capacity of the connection to the footings. Though this was not identified to provide a loss of gravity support, it may produce an undesirable failure mechanism.

Additional load is placed on the rear frame by the elevated seating at the rear of the Hall. This frame however also lacks the capacity to accommodate the additional loads placed on it.

In the transverse direction, the Hall frames are able to achieve 25-30%NBS. Note that this correlates well to the Spencer Holmes assessment of 40% for Soil Type C.

5.1.2 Longitudinal Direction

In the Longitudinal direction the loads at roof level are taken by the frame columns bending about their weak axis above the parapet line. The loads are then taken by the brick walls acting in-plane.

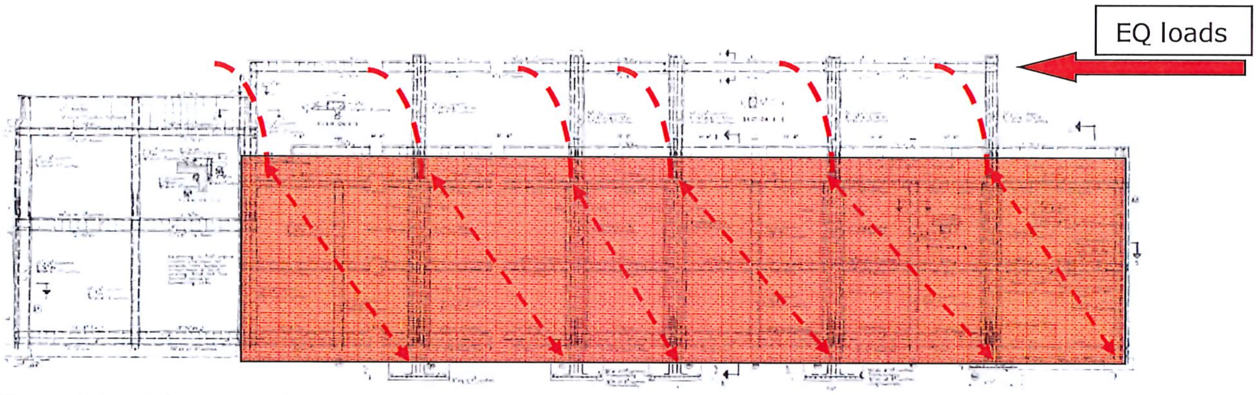

Figure 21 – Schematic of Longitudinal Load path through Town Hall Side Walls

A similar ductility has been allowed for the frame columns in this direction as that used for the transverse assessment. Based on this, these columns are able to accommodate 100% of seismic demand.

In-plane there are long lengths of unperforated URM walls. These walls are also able to accommodate 100% of seismic demand. This also correlates well to the Spencer Holmes assessment of 115% for Soil Type C.

5.2 Municipal Building

5.2.1 Transverse Direction

The façade is supported out-of-plane by the diagonal timber sarking at roof level, and the timber flooring at first floor level. The sarking and flooring act as a diaphragm and transfer loads to the walls acting in-plane. The removal of internal URM walls has compromised the capacity of the building in this direction.

It is worth noting that this may help explain why the building suffered minor damage in the 1943 earthquake series. The internal URM walls would have reduced the span required of the sarking and flooring to act as a diaphragm. The additional wall lengths in plane would have provided additional resistance to seismic loads.

Removing these wall elements has had the effect of increasing the seismic demand on the diaphragms, and reducing the structural elements available to resist seismic loads.

5.2.2 Longitudinal Direction

In the longitudinal direction, the internal URM walls are supported out-of-plane by the timber sarking at roof level and the timber flooring at first floor level. As per the above, the sarking and flooring act as a diapraghm and transfer loads to the façade and rear wall which are acting in-plane.

5.3 Summary of Assessment Results

The following table summarises the assessment results. Note that Appendix A (attached) has several sketches provided which illustrate these results.

Element	**%NBS**
TOWN HALL (Importance Level 3)	
Transverse	
Transverse Frames across Hall (Grids D, E & F)	25%NBS
Transverse Frame supporting elevated seating (Grid C)	20%NBS
Support to the Projector Room	10-20%NBS
Rear wall in-plane	75%NBS
Longitudinal	
Columns bending about their weak axis	100%NBS
URM walls acting in-plane	100%NBS
Rear wall out-of-plane	25%NBS
MUNICIPAL BUILDING (Importance Level 2)	
Transverse	
Diaphragm at roof level	30-35%NBS
Diaphragm at First floor level	30-35%NBS
Façade acting out-of-plane, spanning between roof and first floor, and first floor and ground.	100%NBS
Connection of façade to diaphragms	20-30%NBS
Ground floor URM wall sections in-plane	Grid H – 60%NBS Grids D & E – 60-65%NBS
First floor URM wall sections in-plane	Grid E - 35%NBS Grid D – 60%NBS
Longitudinal	
Diaphragm at roof level	90%NBS (if continuous)
Diaphragm at First floor level	100%NBS (if continuous)
Façade acting in-plane	100%NBS
Ground Floor URM sections out-of-plane	100%NBS
First floor URM sections out-of-plane	30%NBS

Table 1 – Summary of Assessment Results

5.4 Areas with a Potential Loss of Gravity Support

There are local areas within the structure which may be susceptible to a loss of gravity support during a seismic event.

These areas are highlighted in the attached Appendix A sketch titled 'Potential gravity support issues under seismic displacements'.

The main area is the flooring which has been erected over the void between the Hall and the Municipal building. This flooring is supported on a stringer bolted to the hall, and has been previously discussed.

The next is between grids B and C, where floor joists span from the façade to an internal beam adjacent to an in-situ slab section. The joists have only nominal seating on the central beam, and there is no tie across to the in-situ concrete slab adjacent. The in-situ slab sections are tied to the Hall.

The above items are vulnerable to movements expected during an earthquake.

6. Scheme to Improve

The scheme plan developed aims to utilise as much beneficial strength as possible from the existing structural fabric. The schemes are outlined in the attached plans S1-S24 tilted 'Seismic Improvement Scheme, Masterton Municipal Building'.

The following main concepts have been used to shape the scheme;

- The finished structural system should maintain an open floor plan. Over the last 60 years wall sections have been removed from the ground floor and first floor to accommodate internal fit-out. It was considered that a strengthening scheme which proposes to enclose spaces would not be future proof.
- Retain as much of the first floor and wall structural fabric as possible.
- Incorporate the existing façade with minimal changes to the external appearance of the critical line along Dixon St and fronting the Town Square.
- A minimum of 80% New Building Standard was considered.

In general, the aim is to separate the original buildings into three seismically separated structures. The configuration of the structures means that damage will occur where structured with differential stiffness are joined together.

To control this expected damage, it is proposed to separate the buildings. The proposed options for each section are discussed below.

6.1 Town Hall

The Town Hall presents challenges in regards to seismic improvements. The high open spaces must be maintained for the Hall to function. This means that the type of improvements are limited to the existing frame geometry.

The critical issue for the Town Hall is the transverse direction. We have reviewed options to optimise the existing structure, including;

- An assessment of the existing frames' ductility to ensure the correct failure mechanism and likely performance is accounted for.
- Removing the existing brick wall components to reduce the weight and therefore the seismic demand on the frames.
- Remove the existing concrete parapets to reduce weight as per above point.

However due to the configuration of the existing frames the above measures are unable to provide a significant improvement to the seismic performance of the Hall.

The requirements for the Hall would be to basically replicate the existing 'frames'. This would involve;

- Removing all internal wall and ceiling linings
- Cutting into the existing brick section
- Excavating locally for new foundations
- Constructing the new transverse frames. Full scaffolding would be required at each location to allow for construction.

The intrusiveness and scope of these works means the existing hall would be stripped back to a structural skeleton, cut into, and then re-built.

The extent of the works would be similar to that required to construct a new hall structure.

6.2 Municipal Building

The Municipal building scheme relies heavily on making the best use of the existing structural features of the building. These include;

- The 1950s reinforced concrete street façade, being reasonably well detailed and in good condition.
- The 1950s façade has cast-in structural elements which have been adopted into the scheme to secure the façade out-of-plane
- The location of the existing first floor steel beams has been used to determine the moment frame locations.

The scheme for the Municipal Building consists of the following, and will achieve a minimum of 8%NBS for an Importance Level 2 structure;

General

- Local demolition of internal URM walls to reduce the seismic weight of the structure, and remove the need to secure the walls out-of-plane.
- Local demolition of the existing suspended first floor slabs at the entry and original safe areas to reduce seismic weight, and reduce complexity associated with securing the suspended slabs were they to remain.
- Removal of the flooring spanning the void between the Hall and the Municipal buildings to ensure the Municipal building is seismically separated from the Hall.

- Demolition of the URM wall sections along the rear wall line (Grids B and 5) to reduce seismic mass and remove the requirement to strengthen the walls out-of-plane. Removing this weight means the new transverse portal frames are of a more economical size, and the existing first floor and roof plane diaphragms are acceptable.

Transverse

- New two-storied transverse steel moment frames, with a new ground beam footing. These frames have been positioned to also provide gravity support to the existing first floor structure by supporting the original steel beams.
- Connect the new steel moment frames to the concrete façade at eaves level to secure the façade out-of-plane
- Connect the new steel moment frames to the first floor diaphragm to secure the façade out-of-plane

Longitudinal

- New eccentrically braced frames along the rear wall line, both on the ground floor and first floor
- New external wall line footing
- New light timber framing to replace the URM walls and provide the water-tight envelope to the building adjacent to the Hall structure.

CONSTRUCTION NOTES

- The scheme allows for retaining the existing concrete 'banding' along the rear of the Municipal building adjacent to the void between the Hall. This will provide gravity support to the roof while works are being completed. Temporary propping to the first floor will be necessary.
- The transverse moment frames could be installed in stages. This could act as temporary propping to the façade, as well as being incorporated into the permanent structural system.

7. Limitation of Report

This report has been prepared solely for Masterton District Council. Any reliance on this report by third party members is at their own risk.

The assessment is limited to section B1 Structure of the New Zealand Building Code (NZBC) for seismic loading, and no assessment for compliance with other sections of the NZBC have been undertaken.

This report does not quantify any risk associated with geotechnical conditions.

8. Summary

Having reviewed the Municipal Buildings on the site, and their multiple alterations over the last 100 years, we note the following;

- The works required to improve the Hall are substantial, and of a scope similar to constructing a new Hall structure.
- The works required to the Municipal building to 80%NBS are as shown in the attached plans S1-S24 tilted 'Seismic Improvement Scheme, Masterton Municipal Building'. The scheme presented will require a total refurbishment of the building interior.
- The future use of the Municipal building will dictate the final shape of both the structural and architectural requirements.

Further guidance is required prior to completing a full structural picture. This would include looking at the site as a whole and what the Council and community would like from the buildings in the future.

Prepared by

Michelle Grant
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Reviewed By

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Dunning Thornton consultants

Ref: 7903 L02

6th January 2017

Masterton District Council
Email: pimb@mstn.govt.nz taniam@mstn.govt.nz

Attention: Peter Whisker & Tania Madden

Dear Peter & Tania

Masterton Town Hall Redevelopment Review
Outline Peer Review and Options Evaluation

As per our proposal 29th November 2016 our review of the LGE report (Revision A 27th September 2016) is provided below. We also append the proposed "one-page" summary of the issues to assist with the understanding of the complex detail of the assessment and options to assist with your internal and public communications.

Peer Review:

General Aspects:

We agree assessing the code (NZS 1170.5) site seismic subsoil category as D. We note that the report does not consider other geotechnical aspects: where these may possibly be significant structurally, we have noted in our review below.

We note there is good correlation between LGE's calculations, our approximate checks as part of this Peer Review, and the work previously undertaken by Spencer Holmes (given site subsoil category as above). We believe this should give you the client and the public good confidence in the conclusions regarding the current status of the building.

We have not carried out any review of the "Civil Defence" areas of the site (2 buildings): though structurally separate they are somewhat continuous from a user's point of view especially with the Municipal Building at the upper floor. As such any strengthening/redevelopment scheme should consider how the buildings interrelate to get their most efficient use. We also note the Chapel St Civil Defence building is quite unusual in structure and may benefit further assessment if appropriate as part of an overall site master planning exercise.

Both the Town Hall and Municipal Building are irregular in the distribution of mass/seismic resistance in plan. This has been accounted for in LGE's analysis by acknowledgement of the weakest element. In many cases there is torsional stability sufficient to redistribute this mass to other areas. This will make available additional capacity and damping to the structure, but is likely to cause greater damage as this occurs which may include localised falling hazards from small sections of concrete or masonry. The differences in strength by taking this alternative approach are not sufficient to change the conclusions of the report, and these localised damage hazards may not be considered appropriate for a "public" building such as this.

The LGE report identifies areas where there is low confidence in the ability of the floor-carrying gravity structure to continue to perform dependably when subject to large displacements. We commend this as it picks up the sentiments in the new draft of the NZSEE assessment guidelines, and the recent amendment to the loadings code for new buildings.

The target retrofit level of *80%NBS* is reasonable: our experience of similar projects is 70% as a minimum. We suggest any detailed design targets as near as practical without significant cost penalties, with the agreed percentage (80%?) as a minimum.

Importance Level for the whole complex needs to be considered carefully. Firstly it is our assumption that the "Civil Defence" buildings are just offices, and are not intended to perform dependably in any post-disaster recovery other than any regular structure. Secondly and more importantly the classification of the Town Hall as Importance Level 3 (having a capacity for more than 300 people in one space) implies the egress paths from this must also be IL3: this involves the area to the south of the Town Hall in the Municipal Building. As the buildings interact, it will be important that any loss of stability of the lesser IL2 sections do not cause life safety issues in the IL3 sections and the egress paths. To this end, any scheme should carefully consider the interaction/interrelation between the two zones of the complex, including whether the Municipal Building warrants a greater than IL2 capacity in some aspects to ensure this.

Town Hall:

Assessment -

We agree with the general findings of the LGE report for the existing capacity of the Town Hall. We have two additional concerns not identified explicitly in the report.

Firstly is the stability of the heavy concrete Projection box for longitudinal loads supported laterally only at (the different levels of) the Municipal Building L1 ceiling/roof, the L1 seating tier in the hall, and the Hall roof. All of these are relatively weak and flexible with respect to the mass of the Projection Box. We do not however believe Projection Box is likely to become unstable at loads less than the transverse capacity of the Hall structure.

Secondly and less critically we believe it is unlikely that the fibrous plater lining to the walls to be secured back to the underlying structure with full code loadings capacity. Extrapolating from our experience with this type of structure it will have a capacity greater than the transverse capacity of the Hall. This is considered critical due to the large height sections of plaster could fall from.

Retrofit Scheme-
The scheme involving demolition and replacement of the existing concrete portals is a practical baseline. We do not believe removal of brick in addition to these is worthwhile if the existing building is to be retained. The scheme is effectively a rebuild of the 1950's intervention and we agree it is likely to cost in the same order as rebuilding new. Significant use could be made of the more robust stage house structure, which could comprise more of a retrofit rather then re-build (refer options study).

Municipal Building:

Assessment-
We agree with the general conclusions for strength and robustness in the LGE report. We believe the capacity of the building may be a little lower than assessed as the rocking of the internal walls is typically at foundation level which is not quite as energy-absorbing and stiff as rocking at a bed-joint: depending on the underlying soil stiffness. However, provided there are stiff non-liquefying gravels under the foundations the effects should be very small.

We also believe the performance of the longitudinal wall on the hall side is likely to be poorer than has been (and can practically be) assessed due to the irregular arrangement of the openings. The panels are likely to break in to irregular shapes which change with the direction of loading, and as a result walking/ratchetting degradation is likely to occur.

Our assessment of the connections of the façade to L1 are slightly higher than LGE's, but slightly lower at roof level. Neither significantly changes the report conclusions.

The other geotechnical-critical aspect of the building is the existing small foundations under the north-east end internal columns. Their performance and the redistribution of loads in the case of settlement would warrant further investigation if the floor structure were to be retained as-is.

Retrofit Scheme-
The scheme assumes that open-plan area will be required: given the alterations that have occurred over time, and trends in modern offices, we believe this to be prudent. Refer to the alternatives section of this report for further discussion.

In general we agree with the structural form and choice of materials, and believe these are appropriate as a baseline. We would recommend the use of stiff EBF frames instead of CBF's as they are more seismically resilient for negligible additional cost.

The transverse frames rely on their base fixity to be stiff enough to keep the various areas of the building compatible: though not explicitly identified appropriate costs should be allowed for the connections of the frames to the foundation beams.

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We query the benefit of retaining the rear 1950's concrete strengthening bands to support the roof: propping may be of a similar cost to the careful demolition that would be required to work around the retention of these.

Another "buildability" consideration may be offsetting the new frames from the existing truss lines to allow more working room inside the building during construction (if ceiling joists temporarily removed), and more ability to recess the upper floor beam into the ceiling space. Again this would have little effect on preliminary costings at this stage.

Options Evaluation:

The following alternatives to the baseline scheme presented by LGE provide some flavour of the extent the project could be changed to best suit different intended uses of the whole site. We note that given the extent of intervention required for both buildings, the non-structural component of any strengthening scheme is likely to be of the same order of cost as the structural component, or potentially more. As such, it is important that any scheme is based upon an efficient, future-looking masterplan of the site that makes most economic use of the facilities needed by the Council/Community.

The options presented below result from a strengths/weaknesses analysis of the existing fabric, and include a brief pros-and-cons appraisal to assist with understanding the option further.

Town Hall:

<u>Traditional Hall/Theatre Strengthening:</u> this would involve additional (likely sprayed concrete) walls to the stage house and foyer ends of the auditorium, with significant horizontal roof bracing through the auditorium ceiling. The intent of this option would be to keep as much of the existing fabric in place undisturbed as possible. However the new elements would be significantly expensive: installed within the constraints of the existing fabric. This would be especially so for foundations, as hold-down piles are likely to be required at the ends of the new wall elements. The heavy nature of the existing structure would make this more expensive relative to similar projects in other theatres/halls.

<u>Strengthen the Current Elements:</u> strengthening the existing portals would likely involve post-tensioning the existing roof beams and adding new columns alongside/integral with the old. The existing columns would be cut at the underside of the roof beams, and energy dissipation added at the connection between the new columns and the roof beam. Additional roof bracing would be required around the projection box. The rear stage house wall mullions would need to be strengthened for face loads with corresponding ties and bracing in the roof. This option has the advantage of retaining much of the existing fabric, but the costly result is of much of it being affected by strengthening work with high structural demand from the heavy weight existing structure.

Rebuild Retaining Useful Existing Elements: the useful existing elements we believe are the existing floor, the tiered seating, and the stage house. The cost savings of not having to re-build these items would be offset to a small degree by the costs of temporary protection and disturbing the sequence of works. The actual usefulness of these elements should also be interrogated, especially the suitability of the stage house geometry and flying system for future productions, and the seating tier geometry (noting the unit complete could be lowered or raised to suit the new building).

Re-building: many of the advantages of re-building relate to the sequence of works for the Municipal Offices, and the ability to create a purpose built venue to match the current needs of the community. Combining the two structures does provide more alternatives for the lateral bracing to the new hall. Tall frames are structurally inefficient, and it may be more economic to provide the lateral structure for both buildings on the two-storied portion as a "buttress". Alternatively space for more efficient braced frames or walls may be able to be provided between the two structures (currently the old lightwell area). The disadvantage of combining the structures is that the whole building would need to be IL3.

Municipal Building:

Modifications to LGE Scheme: the current scheme has a clear span across the new office space: structurally it would be cheaper for the new seismic frames to be two-bay rather than single bay, leaving a column centrally in the space (for the lower floor). This obviously has future planning disadvantages but this may be acceptable balanced against cost (and the smaller beam/column depths).

The new structure could also be reinforced concrete rather than steel: frames across the buildings and walls substituting for the braced frames. The structure would be larger, heavier and more labour intensive to build, and in our experience of a similar cost/more expensive than steel.

Cellularisation: the building is rather large, and if in planning terms it could be considered as three to four planning "blocks", bracing (likely k-bracing) could be introduced between these blocks. Bracing in our experience is more cost effective than moment frames. This may be seen as too great an architectural/planning flexibility compromise though.

Façade Retention: re-building new behind the existing façade has the appeal of cleaner planning and buildability, but it is our experience that the cost of temporary works to hold up the façade (lost investment) is significant. This may be able to be avoided by careful planning and sequencing, working in shorter lengths down the building demolishing and rebuilding in sequence (which re-introduces complexity).

Combined Building with New Hall: if the new hall is built first, and has its own lateral load resisting system the existing Municipal Building roof may be able to be re-supported off this new structure. This would allow cheap "façade retention" using the roof to brace the top of the façade while the building is demolished and re-built inside. The re-build would not have overhead crane access, but with modern telehandling equipment this is not seen as too significant a penalty.

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Combined Building with Vertical Extension: if the buildings are to be a combined unit, the new hall is likely to be taller than the Municipal Building. Re-building the Municipal Building to three floors may significantly simplify access to the multiple levels of the auditorium and stage house, and would potentially be more economic than building the same space freestanding elsewhere. This assumes more functions/economic returns are available for a larger building.

In summary, we believe the LGE scheme provides a good baseline to understand the costings of a pure strengthening/replacement of the existing facilities like-with-like. However we stress again we believe it is essential to consider the future use of the whole complex before any scheme is undertaken. All strengthening schemes involve significant disruption of the existing building fabric: if many non-structural elements are to be removed and "put back" the form they should be "put back" in requires careful thought outside just structural engineering.

We trust that this provides you with a good understanding of the potential structural options associated with this complex redevelopment/retention proposal. We would be happy to talk via VC/Skype or meet with you should you wish to discuss this report further.

Yours faithfully

Alistair Cattanach
DIRECTOR
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Dunning Thornton consultants

Masterton Town Hall and Municipal Building: Structural Peer Review and Options Evaluation

Dunning Thornton have reviewed the seismic assessment and strengthening report prepared by LGE (Revision A 27th September 2016) and supporting documentation and generally concur with its findings. The buildings are approaching 100 years old, and the seismic strengthening carried out to them is over 50 years old.

The scope of seismic retrofit required to both buildings is very extensive and will affect much of the existing fabric, and hence in our experience carry a non-structural cost on the same order as the seismic strengthening cost. It is also expected that the seismic retrofit cost, with all make-good, disabled access and fire compliance requirements may be in the same order of cost as replacement with a new building (though unlikely to have a façade of the same quality as the existing). The LGE scheme for the strengthening of the Municipal Building we believe is a good baseline to assess this.

The only significant item we believe the report overlooks is the Importance Levels targeted for the buildings. If the hall is going to cater for more than 300, it becomes a place of assembly (Importance Level 3 – IL3) and has to be designed for 30% more seismic load than a "normal" building. If the Municipal Building is only going to be designed for IL2, the egress from the hall cannot go through this weaker portion which significantly affects the planning/orientation of the new hall. Alternatively the areas of the Municipal Building that contain egress or could affect the hall could be designed for IL3.

The scheme prepared by LGE will give a good baseline costing to understand the relative cost between the significant strengthening required, and a comparable new building provided the appropriate allowances are made for the non-structural aspects of the scheme. We believe there are several items of valuable fabric in the buildings (the façade, the roof trusses, the hall floor, stage house and seating tiers). We believe economic seismic strengthening is about creative re-use of high-value items, and efficient strengthening/re-building of the remainder. The sequence of how the project is carried out will play a big part in this, and consideration could be given to joining the buildings to assist this.

Most importantly we believe a master-planning exercise should be carried out to understand what the Council/Community want and can use from the complex, and creative solutions be generated from this using a combination of strengthening and new build.

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Peer Review Report

64 Chapel Street, Masterton

Masterton District Council

Reference: 2790-8779

19 January 2017

emajineer
the possibilities are endless

Structural Concepts

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Executive Summary

Structural Concepts Limited have been engaged by Masterton District Council to review the report completed by LGE and the seismic enhancements proposed.

The LGE Report provides a good basis to move into the next phase of the process of enhancing or otherwise the seismic performance of the building. There is some missing information and minor errors but this does not detract from the usefulness of the report.

The next phase should carry out further work as required that includes more accurate assumptions and modelling. This will allow the development of different concepts for strengthening. It should also include a geotechnical investigation.

The design team for this next stage should include an Engineer experienced in the restoration and strengthening of similar buildings, particularly for the Town Hall. In the LGE Report, only one option is provided which restricts the evaluation process. We believe that more strengthening options could be developed which would provide the stakeholders with a greater ability to make better informed decisions.

Contents

1. Purpose

We have been engaged by the Masterton District Council to review a recently completed Structural Report by LGE Consulting on the Masterton District Council Municipal Buildings and Town Hall structures. The purpose of the review is to determine the correctness and accuracy of the report and comment appropriately, plus review any seismic upgrade initiatives proposed, comment on those plus provide potential alternatives where appropriate.

2. Background

In 2007 the Masterton District Council requested a seismic review of the Municipal Buildings and Town Hall be completed by Spencer Homes Limited. This report provided a score of 40% NBS.

In 2016 the Masterton District Council requested a further report be undertaken by LGE Limited. The purpose of that report was to confirm the findings of the Spencer Holmes Report and determine what is required to improve the seismic compliance of the buildings. A scheme showing potential compliance to greater than 80% NBS was provided. The score provided by LGE in the executive summary for the existing buildings is 30% NBS.

The difference between the two report findings was identified as due largely to the chosen site geology.

The works to improve the structural performance have been defined as substantial for the Town Hall and significant for the Municipal Buildings.

3. Review Criteria

The criteria used to complete this peer review is technically benchmarked by the latest NZSEE guidance document, "The Seismic Assessment of Existing Buildings" published in June 2016 as a "draft" and subsequently re-published as a 'Review Draft" in October 2016. This document is to be further be identified in the New Provisions of the Building Act as a means of compliance for assessment which will come into force in July 2017.

It is important to note that seismic assessment is a judgement-rich exercise and should therefore be appreciated that there will always be a degree of variation between assessments.
It is our understanding that the LGE brief was as follows:

"Review the Spencer Holmes report, complete some calculations to confirm or otherwise compliance levels and provide a potential scheme to improve the structure."

As such our review will be broader than is usual to capture intent rather than specifics and only focus on error where this is likely to have a significant effect on outcome.

Unlike design, conservative approaches in assessment can provide poor outcomes when choosing the assessment parameters affecting the demand requirement. To illustrate there is little objection to a building that has been designed conservatively as it will result in a higher %NBS, whereas the conservative criteria will result in a lower %NBS evaluation for an existing building that may cause unwarranted or unnecessary concerns. We will attempt to give a balanced view in this area of the assessment.

4. Geotechnical Discussion

The choice of soil type within the loadings standard changed between loadings standard NZS4203 and NZS 1170.5. This has had a major impact upon seismic demand requirements and caused some confusion during the introduction of NZS 1170.5.

Previously it would have been acceptable to use site subsoil category 'B' as described in NZS 4203. In NZS1170.5 site subsoil class 'C' is similar to this and hence was accepted at the time by most.

The Spencer Homes 2007 report utilized site subsoil class 'C' in their assessment. At the time this was generally accepted site subsoil class for Masterton when compared to the earlier loading standard NZS 4203.

LGE have referred to a recent geotechnical study carried out by GNS Science in 2008 which shows the Masterton Urban area as site soil class 'D'. We agree with LGE that this directly influences the magnitude of forces or demand on the building structure. We also note how close the site is to the boundary between site subsoil class 'C' and 'D'.

We are also aware that a specific study can be completed to more accurately determine the soil type and spectrum to be used. Considering the sensitivity of the outcome it is our opinion on this occasion that a specific geotechnical investigation be completed to accurately determine seismicity at this specific site.

We agree that the soil type chosen was the correct choice in the absence of specific knowledge or assessment.

In conclusion site subsoil class 'D' is acceptable but specific site assessment could be completed for the next phase to provide a more accurate assessment.

5. Load Demand Parameter Discussion

As for the geotechnical soil parameter choice, the parameters chosen to determine the load demand are also sensitive in nature. The parameters the assessor has control over, and must use judgement on, are the Building or element period, element ductility, element stiffness and mass. These directly influence the load demand outcome.

Unlike design, where the designer can choose these as they desire, in assessment the assessor must carry out back calculations to determine these. LGE have carried out these in a technically reliable and considered manner. This has resulted in much better outcomes than if they had accepted, as many designers would, lower ductility and lower periods.

Unfortunately it appears they have not fully trusted their own findings which have resulted in lower %NBS than possibly available. An example of this is the concrete frame to the Town Hall where they have calculated a period of 1.0s and ductility of 2.0 but used 0.8s and 1.8 respectively in their assessment. The influence of this is a potential %NBS of 32% as opposed to 26%.

Again as there is no evidence otherwise we assume the assessor has not used reduced section sizes to determine element period. They have also decided to not include the influence of the mass from the brick wall in the determination of period for the Hall concrete frame. Both of these will have the influence of increasing the building period and hence lowering the demand. Again an example of the influence on the abovementioned frame is as follows:

1) Reduced section size due to cracking etc increase in period by 15%
2) Add weight from brick walls etc at parapet level will increase the period by 5%

Now using a period of 1.0s increased by say 20%, the demand is reduced to 0.33 as opposed to the value of 0.458 used and hence, the %NBS could potentially increase to 36%. Other factors could potentially increase this again.

However the outcome is not likely to result in a %NBS greater than 80% for the building as a whole as desired by the Council. Until the design stage begins further refinement of the %NBS is a futile exercise.

This could change of course if it was found that site subsoil class 'C' was appropriate whereby the %NBS could potentially increase to 60% NBS.

Therefore the parameter choices need to be careful and considered. A review from an engagement with an independent experienced chartered professional engineer at the design stage is recommended to ensure good evaluation and design parameter selections.

6. Importance Level Choices

The importance levels chosen match those found in table 3.2 of NZ Standard NZS 1170.0 for the areas evaluated. What has not been taken into consideration is the interaction of the sections evaluated with each other.

The Town Hall has been allocated as importance level 3 and the remainder as importance level 2. It is noted that the Civil Defence Building is not included in this assessment of the building and that this section appears to have been separated from other structure by seismic gaps.

We are concerned with the areas selected as IL2 and IL3, as some IL2 areas are directly linked to IL3 elements. This does not appear to have been taken into account in the assessment. This may be because it is intended to seismically separate the different areas during the improvement stage.

However for the assessment this should, in our opinion, have been considered or at the very least noted.

7. Modelling of Structures

In the assessment only 2D modelling has been carried out, with tributary areas used for loads. This is appropriate if a broad overview is required that would allow a more specific assessment to target the more vulnerable areas. This choice is valid where the assessor is discovering the vulnerable areas to allow concept development and the outcomes are not so critical. 3D modelling is more appropriate where the structure becomes complex and interaction between structural elements is very likely, and therefore a more accurate assessment can be achieved.

Modelling of the structure, regardless of whether it is 2D or 3D, will significantly affect the outcome of the results. The models should reflect the real structure as closely as possible, and not become too simple or overly complex. In the case of this assessment, it is our opinion that the modelling does not necessarily always reflect the structure well enough to be able to accurately define the %NBS. We would recommend discussion with other experienced Engineers to get agreement.

The outcome of better modelling on this occasion however will likely still result in %NBS scores that would result in strengthening enhancement requirements, especially considering the target is 80%NBS. At the next stage better modelling should be employed that better reflects the existing structure plus 3D modelling should be considered especially where interaction of structural elements is likely.
An example of this is at the stage area where different frames and walls can interact.

8. Report Review

The LGE report provides a comprehensive historic view of the structures past and alterations. It also provides a reasonably accurate description of the structural elements and how the seismic resisting structures work.

It does however make the mistake of assigning a %NBS in the executive summary of 30% NBS whilst in the table it is noted that some areas are or could be as low as 10% NBS. It is normal practice that the lowest score be used to define the overall building %NBS regardless of the localisation of that element. For example if a chimney has a %NBS of 10% NBS and is likely to cause harm to life or damage to other property but the main structure is 55% NBS then the score is 10% NBS. Obviously the report should identify and quantify the risk so that alarm bells do not ring unnecessarily. Other than in the executive summary the overall building score is not noted.

In section 4 the report states that "The Capacity of each direction needs to be independently assessed". This statement is not strictly true as there is a requirement in standard NZS1170.5 that states differing requirements for different levels of ductility. The Statement is true where ductility or limited ductile design is considered but not so where nominally ductile or brittle (elastic) design is considered. Also concrete standard NZS3101 has a requirement for considering concurrent effects. The calculations do not appear to have taken this into account. The nature of the 2D assessment in many ways precludes this. The assessor may have reasons for not carrying out this check but this has not been identified in the calculations or report.

There is no specific intention or purpose stated in the report body as to what the report is to evaluate. From the report executive summary it can be deduced that the purpose is to:

1) Complete re-assessment based on the soil type "D" and compare that with the original completed by Spencer Holmes in 2007,
2) Complete a review to determine what is required to improve the seismic compliance for the Buildings
3) Provide an improvement scheme to enhance the strength of the building to greater than 80% NBS.

It seems that the intention is not to be specific but broad in that it concentrate on the main structural issues as opposed to covering all aspects. Email correspondence between Structural Concepts Ltd and LGE confirm this.

On that basis our peer review is also less specific and will be focussed on outcome and recommendations and the assumptions that influence these.

For the Town Hall transverse direction, Section 5 clause 5 1.1, it states the %NBS being in the range of 25% - 30% NBS yet the summary table shows that this is in fact in the range of 20% to 25%. The assessor should explain their conclusion as this can be confusing for the reader.

There is no mention of the low % rating elements or explanation of why such low levels are achieved. Examples of this are the "support to the Projector Room" at 10-20% NBS and the "Rear Wall out-of-plane" at 25% NBS in the longitudinal direction. Some explanation of the issues relating to the low scores should be provided so that the reader can understand the problems and risks.

There is no mention of the URM wall assessment for the Town Hall structure.

The results noted in the calculations do not necessarily correlate with that identified in the report.

The Municipal Building assessment does not state any specific ratings, (other than in the table) but does identify the main concerns around the diaphragm's ability to span between the main lateral resisting elements. Other than that, the report does not go into any further details. We would have expected at least some comment on the connection of the diaphragm to the facade as this looks to be a critical item to be addressed in further works.

This area of the report lacks discussion around the low rated elements and the problems that could result in dealing with these.

There is no discussion around the consequences of damage to the IL3 section due to early failure of the IL2 section.

The table while extensive, is not always consistent with the results found in the calculations and lacks scores for the out of plane check on the Town Hall URM walls plus the in plane assessment of the URM Walls in the Municipal Building in the longitudinal direction. The table does not address the area 2 structural elements.

We agree with the assessment of "Areas with a potential loss of Gravity Support". It could be appropriate to identify the risks associated with the IL2 and IL3 structure connection at this point.

With regard to the scheme to Improve section of the report this is reported on separately in Section 10 following.

The summary suggests that the works required to improve the Hall are of a scope similar to constructing a new Hall Structure. This is based on the assumption that the only method of enhancement is to completely replace the existing concrete frame structure. This statement precludes the fact that there may be the other options the assessor has not thought about or been able to identify. It is our opinion that other options are available that are less destructive and more cost effective and these should be explored before a decision is made to completely replace the Hall.

We agree that further guidance is required prior to moving forward so that a scope can be identified. However currently the only choices provided to the Council are those of significant works or replacement and before Council makes further recommendations or decisions it should obtain a fuller picture of the options available to it.

9. Calculation Review

In general the identification of ductility, structure period and assessment of individual element strengths are compliant with current practice and are reliable.

There is one area of calculation that has not been executed correctly and that is in relation to k_μ. It is quite clear in NZS1170.J the k_μ has two identifiers dependent upon period. If the period (T_1) is greater than or equal to 0.7s the $k_\mu = \mu$. Where the period, (T_1), is less than 0.7s then $k_\mu =$

$$(\mu-1)\frac{T_1 + 1}{0.7}$$

LGE have used $k_\mu = (\mu-1)\frac{T_1 + 1}{0.7}$ in all their assessments and calculations for Cd.

If $k_\mu = (\mu-1)\frac{T_1 + 1}{0.7}$ is used for periods above 0.7s, then k_μ becomes smaller in magnitude and thus produce a nonconversative figure for Cd (Seismic Coefficient).

This is an error in the calculations. As this is an evaluation assessment only, it has less of an effect as the building already has %NBS rating less than 34%. This must be corrected in any future design.

Other than that we did not identify any other technical errors that might have a significant outcome.

Our review did identify areas of concern around assumptions and modelling. The over simplification is acceptable if the purpose of the report is to verify the Spencer Holmes report and identify the areas where works will be required to improve the seismic compliance of the Hall and Municipal Buildings.

Therefore the results should not be taken as specific but as identifiers and approximate only. This is especially so where results differ between the calculations and report.

The assessment of the rear wall and projector room support was difficult to follow and not comprehensive. We suspect this is due to the complexities around these areas. They have both been identified with low scores and hence will need greater evaluation in the future.

There does not appear to be any calculations for the assessment of the area B2. It appears this area has been identified as a risk and hence improvement design only has been looked at here.

As stated in the report section, no calculations for the Town Hall URM out-of plane direction were found.

10. Improvement Review

LGE have only provided one enhancement scheme for each section of the Building. We are not aware of any other options looked at other than to reduce weight or complete replacement. We address each of the options chosen separately below:

1 **Town Hall**

The only option looked at, other than reducing weight by removing brick walls, is to completely replace the existing reinforce concrete frame structure. Due to the amount of destructive works involved in this process they have concluded that this would be similar to demolition and complete replacement.
We do not disagree with this conclusion. However we do believe there are other options available that should be explored that do not require the same amount of destructive works.

In assessing any strengthening enhancement concept the main concerns should be identified first. In the case of the Hall some of these could include:

1) The Building concrete frames lack reinforcement to resist tension forces within the concrete elements.
2) The rear wall lacks out of plane support.
3) The projector room support structure requires enhancement.
4) The internal finishes and fixtures etc are extensive and worth keeping and not disturbing wherever possible.

Secondly the positive elements should be identified, some of these could be:
a) The Building potentially has a rating of 100% NBS in the longitudinal duration.
b) There is room external of the building and between the Hall and Office Buildings on Chapel Street.
c) There is space in the roof space to carry out works.

From here different concepts can be explored and discussed with stakeholders where be decisions can be made. Some concepts that could be explored could include:

a. Replace existing primary frames (LGE option)
b. Enhance the primary frames with external tension elements
c. Provide external stiff elements to attract load away from the primary frames
d. Complete replacement (LGE option)

2 **Municipal Buildings**

The option chosen here is to install a new two storey steel structure that is capable of resisting lateral loads. This requires new foundations and penetration of floors plus attaching the existing structure to these frames. The work is extensive and as noted by LGE likely to require complete internal refurbishment. It does come with the benefit of being able to open up the space to allow future refurbishment without affecting the structure.

In identifying the problems for this area focal issues could include but are not limited to:

a) diaphragms lack stiffness and strength
b) the portal on grid H is deficient
c) Upper level out-of plane strength of URM walls requires enhancement.
d) Attachment of diaphragms is deficient.
e) Upper level in-plane strength of URM walls requires enhancement,

Positive elements could include but not limited to:

a) Lower URM walls are providing %NBS at an acceptable level and easily enhanced if needed
b) Out-of plane URM walls are acceptable at ground floor
c) In plane and out-of plane strength of facade is at an acceptable level
d) Lower URM walls adjunct the Hall are acceptable

Other concepts (but not limited to) to consider:

a) New steel portal frame and brace frame structure (LGE Option)

b) Enhance current vertical structural elements as necessary and provide a new diaphragm (a steel truss system or plywood diaphragm) at each level to take loads to these vertical elements

c) Concentrate forces to a few main vertical elements and bring loads to those similar to b)

d) Complete replacement

In conclusion we are of the opinion that more options need to be considered in the next phase. We would also recommend that an Engineer experienced in restoration and strengthening of Heritage Buildings who has had experience with providing many different solutions to different problems, be engaged in the team especially for the Town Hall.

11. Conclusions

- The purpose of the report is not clear and therefore we have made assumptions around this and had discussions with LGE regarding their scope.
- There is missing information and some relatively minor technical errors. This is not a problem if the intention of the report is to identify and verify rather than specifically report.
- Conservative assumptions have been made in places which have resulted in lower %NBS scores. This is not a problem if the intention of the report is to identify and verify rather than specifically report.
- The modelling is simple and does not always accurately replicate the real structure. This is not a problem if the intention of the report is to identify and verify rather than specifically report.
- The %NBS in the table do not always correlate with those in the calculations.
- The Building %NBS reported in the Executive Summary should be justified as it is different from the table.
- The options chosen for the scheme to improve are very intrusive and likely to be costly. At this stage only one scheme appears to have been assessed or put forward for each building other than demolition and replacement. Other options are available and should be explored.

The report is sufficient in nature if its purpose is to "identify and verify, rather than specifically report, and provide information for future concept design". It should be used as a basis of identification only for the next phase of the building enhancement process.

12. Recommendations

We have the following recommendations relating to the report:

- That the report be used as a basis for identifying the areas that require seismic enhancing
- That at the next phase more accurate modelling be carried out to closer reflect the real structure.
- That a geotechnical study be completed to provide an accurate and custom site specific spectral curve if deemed appropriate.
- That any design is peer reviewed.
- That further investigation be carried out into different options available for enhancement.
- That any future work involves a structural engineer experienced in restoration and strengthening of Heritage Buildings who has completed many strengthening designs requiring many different systems so that the most appropriate enhancement system can be utilised. This is especially so for the Town Hall.
- The next phase should focus on creating multiple strengthening concepts based on a carefully prepared functional brief which explore options for repair/strengthening/remediation/replacement.

13. Applicability

13.1 Recommendations and opinions in this report are based in the LGE report, drawings and other supplied information.

13.2 Findings presented in this report are for the sole use of the client. The findings may not contain sufficient information for use by other parties, and as such should not be relied upon unless discussed with Structural Concepts Ltd.

13.3 We have exercised our services in a professional manner using a degree of care and skill normally, under similar circumstances, by reputable consultants practicing in this field at this time. No other warranty, expressed or implied, is made as to the professional advice presented in this report.