Queen Victoria Market Precinct Renewal

Heritage Victoria Submission: Structural Engineering Interfaces. Part A

20 September 2017
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Part A

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### Issue and Revision Record

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Contents

1 Introduction 1

2 Typology of Heritage Sheds at the Queen Victoria Market | Sheds A - D 2

3 Stability of Shed Structures 3

4 Dilapidation Survey and Requirements for Repair 4

5 Proposed Approach to Establishing Stability to Truss Structures Under Gravity and Lateral Loads 9
   5.1 Repair to Columns 9
      5.1.1 Introduction 9
      5.1.2 Identified Scope of Repair 11
      5.1.3 Proposed Timber Remedial Works Methodology 12
   5.2 Column Fixity to the Ground Plane | Column Shoe Details 14
   5.3 Addition of Lateral Restraint to Lower Chord of Trusses 15
   5.4 Lateral Restraint Steelwork and New Lift Shafts 15
      5.4.1 Passenger and Goods Lifts shafts 15
      5.4.2 Steel Portal Frames to Sheds A – D 15
      5.4.3 Steel Portal Frames Above Basement Entry to Shed D 15

6 Disassembly / Assembly Diagrams 17

Appendices 18

A. Sheds A – D: Typology of Defects – Locations 19

B. Sheds A – D: Typology of Defects – Photographic Examples 20

C. Heritage Interfaces – Sketches 21

D. Disassembly / Assembly Diagrams 22
1 Introduction

The proposed redevelopment to the Queen Victoria Market Site will entail both the requirement for working in and around the existing heritage sheds, and upgrading the sheds for use for well into the next 50-100 years.

The existing heritage sheds will be preserved and retained and serve as a key component to the redeveloped site. The proposed development will entail a number of interventions/activities which will support the requirements for both the preservation and restoration of the sheds. These include the following:

- Construction of a basement beneath portions of sheds A to D. This will entail the temporary disassembly and restoration of the sheds on the ground plane which will be supported by a suspended slab above the basement. The disassembly of the sheds will allow for ease of repair and restoration of the sheds prior to, and through the course of, reassembly.
- The in-situ repair and restoration of the remaining sheds A-D.

The repair and restoration of sheds will entail the following primary structural interventions:

- Repair to timber column structures inclusive of connections and base shoe details. Where sheds are being disassembled and a new ground plane slab is being constructed, a new shoe detail will be developed.
- Repair to steel truss structures where these may currently appear damaged
- Improving the lateral and vertical stability and over performance at serviceability of the trusses in order to achieve compliance with current day BCA requirements. We believe an appropriate balance has been struck between proposed interventions and levels of compliance which have in principal endorsement from the building surveyor/relevant authority.
- The disassembly and reassembly of sheds, located above the proposed basement, has also been subject to detailed consideration and aims to preserve the character and integrity of structural members through the proposed sequence of disassembly.

The proceeding report examines the above proposed activities and provides the proposed structural principals and schematic design details which support the preservation and restoration of the existing market sheds.
2 Typology of Heritage Sheds at the Queen Victoria Market | Sheds A - D

The existing heritage sheds comprise a number of typologies throughout the site. The typologies of sheds A-D are provided in summary below. Each truss provides a structural resilience that is characteristic of that typology. As trusses may vary in geometry and materiality, so too will the structural capacity. Hence, it is important to distinguish between shed types across the site as these will inform the interventions proposed across the site.

Table 1: Typology of Typical Heritage Sheds | Sheds A - D

<table>
<thead>
<tr>
<th>Plate ref</th>
<th>b (mm)</th>
<th>d (mm)</th>
<th>t (mm)</th>
<th>Plate Type</th>
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<td>76.2</td>
<td>12.7</td>
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<td>P2</td>
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<td>76.2</td>
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<td>rectangular</td>
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<td>P3</td>
<td>-</td>
<td>76.2</td>
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<td>P14</td>
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<td>tee-section</td>
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</tbody>
</table>

Timber Columns 200 x 180mm "average" dimension, assumed to be red gum species (to be confirmed)
3 Stability of Shed Structures

The existing shed truss configurations suggest that trusses A to D were designed to resist lateral loads through a combination of portal frame action and column cantilever action. Our detailed site review and subsequent analysis of the structures suggests that the curved knee braces that were installed to provide lateral stability were highly over stressed under both ultimate limit state wind loads and serviceability wind loads to the extent where the stability of the sheds has been attributed principally to:

1. The cantilevering action of the columns, and
2. The distribution of load through the roof trusses assisted by the diaphragm action presented by the iron roof cladding.
3. Some sway capacity presented by the knee braces.

Further, a number of top chord, lower chord and vertical brace members were deemed to be over utilised under current Australian Standard design code requirements. The review deemed the structures as non-compliant in relation to today’s BCA requirements. Therefore, it will be necessary to repair and strengthen the existing structures in order to both gain BCA compliance to today’s relevant Australian Standards and to ensure the structures remain serviceable for the foreseeable future.
4 Dilapidation Survey and Requirements for Repair

Following a site survey and production of a dilapidation report by Mott MacDonald, and consequent technical review of the structures, a number of items were identified that will require attention in order to both preserve the longer-term serviceability of the heritage structures, and preserve the heritage fabric of the sheds.

Key findings of the review are summarised in the following table. Supporting survey data may be found in Appendixes A and B.

Table 2: Typology of Defects and Requirements for Repair

<table>
<thead>
<tr>
<th>Defect</th>
<th>Observations on site</th>
<th>Documentation Examples of Observed Defects</th>
<th>Implications</th>
<th>Proposed Method of Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1-1, Section Loss to Timber Columns due to rope friction wear and tear</td>
<td>Damaged Columns that do not meet BCA requirements will require repair or replacement</td>
<td>Where a reduction in section due to rope friction on the timber surface (or similar) has occurred, the resultant observed section loss typically reduces the section to no less than 140mm x 140mm.</td>
<td>Columns graded F14 and below and with a section of 140 x 140 will require replacement. Columns graded F17 and above and with a section loss of no greater than 140 x 140mm may be retained. Columns are yet to be graded. Columns will be identified for replacement once grading of columns are confirmed.</td>
<td></td>
</tr>
</tbody>
</table>

| Item 1-2, 1-3 and 1-9, Out of Position Columns. | Columns have rotated about their central axis/translated out of position or are out of plumb. | The rotation of columns may be principally attributed to vehicular collision loads and applied wind loads. This results in loads no longer being transferred concentrically through members and a high likelihood of damage to connections. | Columns and associated structural interfaces must be installed to their correct position and within the requirements for building tolerances to the BCA. Damage to any connections attributed to member rotation must be repaired. Please refer to drawings SK-157, SK-158, SK170, SK171, SK173 and SK-174 |

Item 1-1, Section Loss to Timber Columns due to rope friction wear and tear

Original Column size approx. 200mm x 200mm
<table>
<thead>
<tr>
<th>Defect</th>
<th>Observations on site</th>
<th>Documentation Examples of Observed Defects</th>
<th>Implications</th>
<th>Proposed Method of Repair</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item 1-4</td>
<td>Loss of Paint to Timber Columns</td>
<td>Paint protection to timber columns has been damaged to many columns to varying degrees. The current paint is a lead based product.</td>
<td>Paint protection will provide better resilience and protection to timber columns from the natural and “market” environment. The maintenance of paint protection to the timber columns is a requirement for the ongoing preservation of timber structural members.</td>
<td>The current lead based paint to columns will need to be removed and a non-lead based paint will be required for application</td>
</tr>
<tr>
<td>Item 1-5 and 1-6</td>
<td>Splitting of Timber Columns to upper sections</td>
<td>Observed column splitting ranges from minor surface splitting with minimal potential for water ingress and negligible impact on cross sectional area, to significant splitting and loss of allowing potential for significant water penetration and significant loss of cross sectional area due to internal and external rot.</td>
<td>The presence of splitting and rot will have a detrimental effect to timber grading and longer-term timber performance. Rot and splitting will need to be addressed on a case by case basis.</td>
<td>Timber will be graded in relation to the presence and prevalence of rot and timber experiencing damage due to the presence of rot/splitting will need to be repaired. Columns are yet to be graded. The wetting and drying of column bases may be attributed to a combination of the proximity of taps to the column bases and the nature of the column base pedestal connection which may capture moisture rather than allowing it to drain. Where possible, new pedestals will be designed and detailed to provide both a better level of strength and durability to both steel and timber interfaces. Refer drawings SK-133, SK-134, SK-160, SK-161</td>
</tr>
<tr>
<td>Defect</td>
<td>Observations on site</td>
<td>Documentation Examples of Observed Defects</td>
<td>Implications</td>
<td>Proposed Method of Repair</td>
</tr>
<tr>
<td>--------</td>
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<td>--------------------------------------------</td>
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<tr>
<td>Item 1-7 and 1-14</td>
<td>Curved knee braces noted as either missing from the truss assembly, deformed or damaged in situ, or no longer support fixed by a complete set of bolts.</td>
<td>Curved knee braces provided a means of stabilising truss assemblies laterally through frame action during the initial design and construction of trusses. Though found to be non-compliant to current day BCA requirements, these are an important component to the visual aesthetic that is the heritage sheds.</td>
<td>Missing knee braces to be restored/ replaced/ reinstated, and all associated connections to be fully reinstated. Refer drawings SK-139, SK-140, SK151 and SK152.</td>
<td></td>
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<tr>
<td>Item 1-8</td>
<td>Plinths supporting columns are in various conditions as noted below:</td>
<td>The plinth supports the columns in bearing, shear and uplift. Plinth conditions will need to be assessed and repaired where appropriate</td>
<td>Plinths will be retained and reinstated in their current positions (supporting columns). Some changes to the plinths may occur in order to accommodate the required structural detail that define the support to reinstated columns. Cracked plinths will be grout repaired. The reinstatement of plinths will be in accordance with the current visual aesthetic/ character noted on site</td>
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<tr>
<td>Item 1-10 and 1-18</td>
<td>Poor bolted connection of corbel to transverse beam. Corbel has loose or missing bolt(s) and/or is separated from the transverse beam. Bolts missing from steel truss assemblies</td>
<td>Missing bolts result in a reduction to connection strength and robustness</td>
<td>Where bolts appear to be missing they should be replaced. Loose bolts should be tightened Refer drawings SK-142, SK-143, SK176, SK177, SK179 and SK180.</td>
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<tr>
<td>Defect</td>
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<td>Implications</td>
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<tr>
<td>Item 1-11 Splitting of Corbels</td>
<td>Visible splitting to corbel to various degree from minor surface splitting to significant, and allowing potential for significant water penetration and further loss of cross sectional area</td>
<td>The presence of splitting and rot will have a detrimental effect to timber grading and longer -term timber performance. Rot and splitting will need to be addressed on a case by case basis</td>
<td>Timber will be graded in relation to the presence and prevalence of rot and timber experiencing damage due to the presence of rot/ splitting will need to be repaired. Timber beams are yet to be graded. Refer to drawings SK-145 and SK-146.</td>
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<td>Item 1-12 Truss bottom chord out of position</td>
<td>Truss bottom chord has visibly deflected/deformed laterally</td>
<td>Deformations to lower chords are generally either due to collision loads (forklifts etc) or buckling of the lower chord due to compression loads (when subject to high wind uplift forces). The lower chord should be acceptable in its current state provided the chord is maintained in a permanent state of tension.</td>
<td>It is proposed to maintain the lower chord in a state of permanent tension through the ballasting of the roof. Ballasting will be facilitated through provision of an insulated sandwich panel which will replace the existing roof sheeting. Refer to drawings SK-154 and SK-155</td>
<td></td>
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<tr>
<td>Item 1-13 Bottom chord of truss unrestrained</td>
<td>Lateral restraint members either noticeably deformed and/or not fully tensioned, or are missing</td>
<td>Lateral restraint to the lower chord has historically provided improved capacity to the chord under compression loads. We note that the lower chord is typically a flat plat and has not been designed to support compression loads of any significant magnitude.</td>
<td>In addition to the provision of roof ballast to maintain tension within the lower chord, it is proposed to restrain the lower chord at node locations through the introduction of lateral restraint members. These will provide additional robustness and improve the buckling load of the lower chord should it go into compression. Refer to drawings SK-148 and SK-149</td>
<td></td>
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</tbody>
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## Defect on site

### Item 1-16
Locally deformed truss members

#### Documentation Examples of Observed Defects

![Defected Truss](image)

- Diagonal/vertical/bottom chord truss member(s) with visible local deformation

#### Implications

Deformations to mild steel brace members are generally due to collision loads over the course of the operation of the sheds. Vertical brace and lower chord members generally are in tension and hence the bent steelwork theoretically will "straighten" under tension loads. Concern lies in the fact that members have yielded (permanently deformed) and that compression members will be substantially weakened by the presence of a substantial "out of straightness" to the geometry which will initiate early buckling.

#### Proposed Method of Repair

The repair of permanently yielded steel work should be facilitated through the off site repair through heat treatment or cold working of the steel. We note that the mild steel has a yield strength of the order of 220MPa – this should remain relatively unaffected following heat treatment and straightening of the steelwork. Refer to drawings SK-154 and SK-155

### Item 1-17
Truss brace member connection missing bolt

#### Documentation Examples of Observed Defects

![Missing Bolt](image)

- Bolt(s) missing from truss member connection

#### Implications

Missing bolts at a connection reduces the capacity of the connection. Any bolts/rivets that are missing from the original truss connection should be reinstated.

#### Proposed Method of Repair

Where bolts or rivets are missing from the truss they should be reinstated. Installation of replacement rivets or bolts should be, at minimum, of the same size and strength grade as existing. Refer to drawings SK-176 and SK-177

### Item 1-19
Column cut and re-joined, typically as a halving joint

#### Documentation Examples of Observed Defects

![Cut Column](image)

- Column has been cut and re-joined, typically as a halving joint

#### Implications

These columns will not have the strength of a graded member given the nature and extent of the recut and re-joined columns.

#### Proposed Method of Repair

Timber will be graded in relation to the presence and prevalence of their state of deterioration. Though columns are yet to be graded, it has been indicated that recut and re-joined columns of the nature noted on site are unable to be graded and will require replacement. Refer to drawings SK-182 and SK-183

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A number of key items emanating from the survey work performed above are further explored in detail below in the context of repairs and intervention work to be performed to sheds A – D.
5 Proposed Approach to Establishing Stability to Truss Structures Under Gravity and Lateral Loads

The proposed method of establishing a shed structure which is compliant to Australian Standards and serviceable for the foreseeable future, and which maintains its heritage fabric will take on the following proposed key design interventions and repairs:

- Repair to columns and column fixity to the ground plane in order to ensure the column base is able to provide rotational capacity and act as a cantilever.
- Repair to trusses and timber members as described in Table 2.
- Installation of lateral restraint members to lower truss chords as described in sketch S-SK-201 in Appendix C.
- The reassembly of purlins and sandwich panel roofing such that purlins only load trusses at node locations (refer sketch S-SK-202 in Appendix C).
- Ballasting of the roof to ensure that the lower chord and vertical brace members remain in tension.
- Design and fixing of the sandwich roof panelling to the trusses to ensure this acts as a stiff diaphragm and lateral brace system to the sheds for purposes of tying the shed trusses together and transferring lateral loads to lateral stability system members
- The provision of additional steelwork which serves to provide a discrete lateral restraint system to the sheds and attenuates lateral movements under lateral applied loads.
- The provision of lift shaft structures loading on the new suspended slab ground plane and which will also serve to laterally restrain the sheds.

5.1 Repair to Columns

5.1.1 Introduction

The columns are generally of a square configuration and made from an unidentified hardwood species, though most likely of Red Gum. The original base detail appears to have been a simple seating detail onto a bluestone plinth which in turn was seated onto a bluestone footing stone. This detail is likely to have incorporated a single dowel pin in iron or steel recessed into both the plinth and the column base.

There appear to also have been areas where the posts were socketed into the ground and seated onto a timber frame.

These details provided only a small bending capacity at the base and, to current codes, these bases would be regarded as pin fixings. It is likely that they do have some small capacity to cantilever.

At around 2002, various options were considered to upgrade these base details and it appears that most posts had new galvanised steel shoes attached at the base. Drawings by Allom Lovell and Associates show bases and fixings which enhanced resistance to uplift and also provided improved base fixity (i.e. provided greater capacity to cantilever). Three options were produced and these are noted below.
Timber columns are generally captured on a steel plate pedestal which is screw fixed to the base of timber columns and spigot fixed into the foundations. Fixity to foundations appears to be achieved either using a 75mm x 75mm iron spigot (Type A and B bases noted below) or a 220mm x 12mm thick plate bolted to the column and embedded into the foundation. It is intended to retain the steel shoe plate section and associated spigot detail for the purposes of this remediation works exercise.

Figure 1: “Type A Base”

Figure 2: “Type B Base”

Figure 3: Base Detail Sections to “Type A and B Bases”
It appears, from site inspection, that various combinations of these proposals were constructed. Examples of as constructed post bases are noted below:

The deterioration includes mechanical damage, such as impact and rope wear and also areas of decay. It does not appear at this stage that termite attack is a major issue, however this might emerge as being more significant as remedial works proceed.

### 5.1.2 Identified Scope of Repair

The identified scope of repair for column bases is noted on drawings S-SK-160 to S-SK-162 in Appendix A. This will require verification from a contractor and timber specialist who will grade timber members and better assess scope through visual and core drill inspections in-order to ascertain the final extent of repair.
5.1.3 Proposed Timber Remedial Works Methodology

The works proposed include epoxy repair augmented, where necessary, by localised timber replacement.

Note that a provisional scope of work has been provided in Appendix A. This should form the basis of scope of repair and will be subject to review and confirmation of a return brief by the contractor in order to finalize the scope.

The works activities are:

1. Review the scope of work identified within Appendix A. Complete a full survey to identify and categorise column bases as:
   - Epoxy repair (Refer diagram A in Figure 8)
   - Epoxy repair with timber indent (timber infill piece which are bolted or epoxy fixed into existing timber) (Refer diagram B in Figure 8)
   - Epoxy repair with new bolts (Refer diagram C in Figure 8)
   - Sound – not requiring any repair.
   - Requires drill testing to ascertain condition beyond surface

2. Drill test the column bases that require further investigation to confirm condition. Use a 6mm or 8mm twist drill of at least 150mm length and record results by orthogonal drilling at column base at 150mm vertical centres working from the base up and mapping the results.

3. Prepare typical standard column repair details in accordance with the design intent shown in diagrams A, B and C, and identify which columns are required to have which repair type.

4. Repair types:
   a. Epoxy repair:
      - Prop as required (this will be determined once the extent of repair, that is established from drill test investigation works, is better understood.)
      - Cut out decayed/ termite damaged/splintered timber
      - Trim edges square to a depth of 10mm minimum to avoid feather edges
      - Shape voids to avoid undercut overhangs so that there are no trapped air pockets
      - Form up a square base as required with greased plywood or similar debonded formwork
      - Clean top surface of bluestone (remove and replace existing dowel pins if necessary) and de-bond surface with Alcor flashing or similar.
      - Screw No 12 stainless steel woodscrews into the sound timber or dowel in 6mm diam stainless threaded rod on a nominal 120mm grid to provide a key for the epoxy. Length of screws/dowels to be confirmed on site.
      - Formwork to have pourable grout access (tube or birdsmouth) and air bleed facility to avoid trapped air pockets
      - Epoxy to be one of the following:
        (i) Megapoxy
        (ii) Sikadur 52
        (iii) Forminex LV 4:1 Epoxy Resin
        (iv) West System 105 Epoxy Resin
      - Epoxy and formwork system to be trialled prior to finalising details
   b. Epoxy Repair with Timber Indent
Where voids are large and the geometry suits, seasoned hardwood indents can be used to reduce the volume of epoxy. These can be either drilled and epoxy dowelled in place and then voids infilled with epoxy as in Section (i) above or they can be held in place against the formwork and epoxy surrounded.

c. Epoxy Repair with New Bolts

Some columns have existing bolts exposed in areas requiring repair. If sound these bolts can remain and be encased in epoxy. If the bolts are damaged or excessively corroded they are to be replaced with new bolts to match existing.

Figure 8: Epoxy Repair Methodology for Timber Columns

<table>
<thead>
<tr>
<th>Diagram A: Establish Propping Requirements for Columns prior to repair</th>
<th>Diagram B: Cut out decayed/ damaged/ splintered timber. Trim edges square to a depth of 10mm minimum to avoid feathered edges</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagram C: Shape voids to avoid undercut overhangs so that there are no trapped air pockets</td>
<td>Diagram D: Formwork to have pourable grout access (tube or birdsmouth) and air bleed facility to avoid trapped air pockets</td>
</tr>
</tbody>
</table>
5.2 Column Fixity to the Ground Plane | Column Shoe Details

The construction of the new pedestal details to the timber column bases is envisaged as follows (shown diagrammatically in drawing SK-204):

- Construct basement and ground plane slab and include cast in 4No. M20 Grade 4.6 hold-down bolts at surveyed column locations to receive reinstated fixing details to heritage sheds.
- Install the bluestone pedestal by threading it through the hold-down bolts and grouting it into a recess in the slab. Bolt holes should also be grouted up.
- Blue stone pedestals will be required to be reworked in size and shape so as to enable the column, pedestal and column shoe assembly to geometrically fit such that the shed assemblies may be reinstalled in the same position in plan and elevation as per their original time of installation.
- Install the steel base plate by threading it through the hold-down bolts and grouting its base to the bluestone pedestal. The steel base plate will contain oversized holes to enable the column shoe to be installed in the correct plan and vertical position. Once surveyed into position, the base plate may be tensioned against the bluestone pedestal.
- Install the steel shoe assembly on the base plate by providing a continuous partial penetration butt weld (PPBW) to the perimeter of the base plate (note that the base of the vertical plate walls of the shoe assembly will be bevelled to facilitate the on-site PPBW).
- Install repaired/replaced columns using 4No. M20 horizontal bolts which engage the steel shoe with the timber columns. These will be screw fixed into a threaded insert which is epoxied into the timber.

5.3 Addition of Lateral Restraint to Lower Chord of Trusses

Lateral restraint members will be added/replaced to join the lower chord of trusses to adjacent trusses. These will also be detailed to support services, such as power cabling, communications, data and security cabling which will ideally be concealed within the tubular member. Members will be fixed to tabs which are mechanically fixed to the existing lower truss chord at nodal locations. Please refer to drawing SK-201 for preliminary details.

5.4 Lateral Restraint Steelwork and New Lift Shafts

Following close consultation with the architect and design team, a series of ground plane interventions are proposed which both support new components of programme to the market shed designs and which have been integrated with the requirements for the structural strengthening of the sheds (refer to drawing SK-197 for plan locations for Sheds A - D). The components are as described below:

5.4.1 Passenger and Goods Lifts shafts

Passenger and goods lift shafts are proposed to be constructed from RHS and SHS sections to form a fully welded vierendeel frame. This will include lift front door way framing and secondary steelwork framing to support interfacing lift mechanism requirements such as lift guide rails, overrun lifting beams and the like (refer to drawing SK-200). Lift shafts will interface with heritage roof elements such as timber purlins and roof sheeting, and ideally will be tied to the roof structure to provide additional lateral stability to roof sheds. New lift shaft structures will interface with existing heritage sheds A, B and C.

5.4.2 Steel Portal Frames to Sheds A – D

The requirement for lateral restraint to roof structures to achieve a satisfactory level of lateral deflection under serviceability conditions has resulted in the introduction of a series of portal frame structures. These will be located such that they will replace existing timber and mild steel trusses at locations as specified in drawing SK-197 with a universal column profile (typically 200UC’s, or equivalent). These will be pinned to new (over the new suspended basement) and existing foundation locations, and will be brought to site as prefabricated moment spliced units. Key interfaces include grouted base and pinned connections of columns through to existing bluestone pedestals, cranked column to pitch roof connection to allow for existing timber crosshead members to maintain their geometry and function in tying together frames laterally, and the support of existing roof purlins which in turn will support roof sheeting elements.

5.4.3 Steel Portal Frames Above Basement Entry to Shed D

The construction of the entry to the basement to shed D will require the removal of the existing shed D structure local to the ramp entry, and the rebuilding of a wider shed structure over the ramp entry in order to cater for the required width of roadway access to and from the basements. The proposed form of structure will be a portal frame (typically 200UC’s, or equivalent) of similar profile to those described as new interventions within sheds A – D, with
the exception of the wider span. These will sit upon a concrete upstand which will define the edge to the opening of the ground plane slab to the new basement.
6 Disassembly / Assembly Diagrams

Refer to drawings MMD-99-DR-S001 to MMD-99-DR-S007 (in Appendix D) for disassembly staging diagrams.

Refer to drawings MMD-99-DR-S020 to MMD-99-DR-S023 (in Appendix D) for re-assembly staging diagrams.
Appendices

A. Sheds A – D: Typology of Defects – Locations 19
B. Sheds A – D: Typology of Defects – Photographic Examples 20
C. Heritage Interfaces – Sketches 21
D. Disassembly / Assembly Diagrams 22
A. Sheds A – D: Typology of Defects – Locations

This section (Appendix A) is included in Part B and Part C of this report.
B. Sheds A – D: Typology of Defects – Photographic Examples

This section (Appendix B) is included in Part C of this report.
C. Heritage Interfaces – Sketches

This section (Appendix C) is included in Part C of this report.
D. Disassembly / Assembly Diagrams

This section (Appendix D) is included in Part D of this report.