

Design Note

Project SIM Sitewide Works
Subject LBC application - Strengthening brackets for scaffolding
Project no 054704
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Revision	Description	Issued by	Date	Approved (signature)
00	Initial Revision	D. Conboy	02.04.24	D. Conboy
P01	Revised following site meeting w/ conservation officers	D. Conboy	11.03.24	D. Conboy

1 Summary

1.1 Introduction

The ongoing sitewide works at the Science + Industry Museum (SIM) include roof replacement and conservation fabric repair works to the New Warehouse building. This requires the construction of scaffolding to all building elevations, plus a full-coverage temporary roof to protect the building's interior during the works. As the scaffold is heavily constrained, the design of the temporary roof places significant loads onto the masonry walls of the building. Buro Happold have been appointed to undertake an assessment of the New Warehouse building to see whether it is adequate to resist these loads, and advise on any works required if the existing fabric is not adequate.

1.2 Executive summary

The assessment undertaken by BH has resulted in the following outcomes:

- This assessment has shown that the existing structure of the New Warehouse is not adequate to resist temporary loads from the scaffolding.
- In order to adequately resist temporary loads localised strengthening is required.
- Several options for providing this strengthening have been explored, but significant constraints within the New Warehouse at L2 mean that most options are severely limited and likely to be infeasible.
- A finalised proposal for providing strengthening brackets to the New Warehouse roof / wall interface has been developed, which is presented in this document.

NB – two separate applications have also been made which cover the proposed scaffolding: CDN/24/0184 & 138261/LO/2023. These are not discussed in detail in this document but reference should be made to these if required.

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2 Structural Assessment

2.1 Scaffold Design

The roof replacement and façade repair works scheduled for the New Warehouse require full scaffolding to all elevations, plus a temporary weatherproof roof. The roof replacement works will likely require significant extents of the existing roofing buildup to be removed at a time, which would expose the building's internals to the elements if not adequately protected. For this reason, a robust temporary roof is an essential part of the works. Figure 2-2 below shows a cross section through the proposed scaffold and temporary roof. For full details of the scaffold design, reference should be made to the separate scaffold design drawings by Bespoke Scaffolding which were submitted as part of application CDN/24/0184.

A temporary roof typically imposes large vertical and horizontal loads onto the supporting scaffolding. These loads can be resisted a number of ways:

- Adding significant additional bracing to the temporary roof to reduce/fully resolve loads,
- Widening the supporting scaffolding and adding kentledge weights to resist the overturning forces,
- Tying into the existing building for support,

The design of the scaffolding proposed for the works at the New Warehouse is constrained, meaning that the first two options are not feasible. Whilst the museum site includes large open areas, free space on site is extremely limited at present due to the various ongoing repair works – both for the upcoming SIM Sitewide works, plus works to the adjacent Power Hall. Constructing a fully braced temporary roof would require assembly of the roof elements at ground level due to the added complexity, which would then be installed via crane. The lack of space to carry out this operation, plus the cost and programme implications make this approach infeasible.

The northern side of the New Warehouse building sits directly adjacent to a shared access road which the museum are not permitted to block due to disruption to neighbouring businesses. As shown in Figure 2-2 the scaffolding at this location has to step inwards towards the building to allow continued vehicular access. As such, installing a wider scaffold to resist roof loads is clearly not feasible. Additionally, the weight of kentledge which would be required to prevent overturning would be significant and there is a clear risk of overloading the basement retaining structures of both the New Warehouse and adjacent buildings. This concern also applies to the southern elevation of the New Warehouse, preventing the use of kentledge in the Upper Yard. These constraints are shown in Figure 2-1 below.

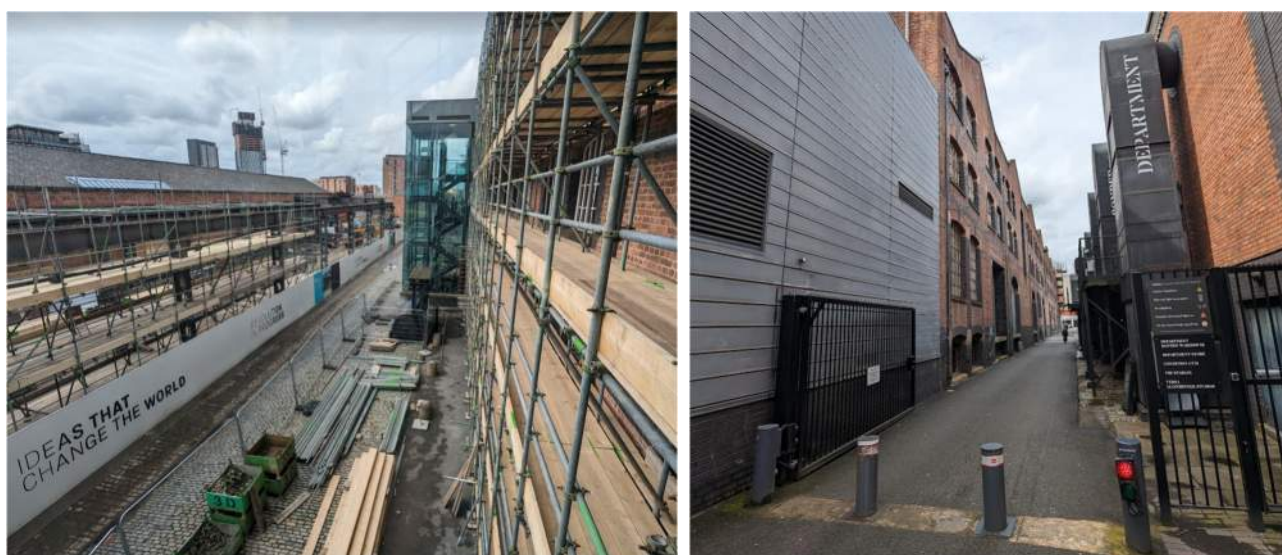


Figure 2-1 Site constraints for scaffolding (L) Upper Yard (R) North passageway

VERTICAL LOADS FROM TEMPORARY ROOF, RESISTED IN SCAFFOLDING & TRANSFERRED TO GROUND.

INWARDS LOAD FROM ROOF UPLIFT RESISTED BY CONNECTION TO EXISTING BUILDING, AS DIRECT LOAD + COUPLE ACTION.

THESE LOADS NEED TO BE RESISTED BY EXISTING BUILDING.

OUTWARDS LATERAL LOAD FROM ROOF BALANCED BY RATCHET STRAPS IN TEMPORARY ROOF TRUSSES.

15.30° FRAME

7 8 9 4 2

INDICATES 5 TONNE RATCHET STRAP REQUIRED EVERY TEMPORARY ROOF TRUSS

34.4KN COMPRESSION AVERAGED TO 23.1KN PER TIE

11.7KN TENSILE AVERAGED TO 7.8KN PER TIE

REDUCED WORKING LIFT LEVEL TO BE MANAGED ON SITE

0.13KN COMPRESSION

0.13KN TENSILE

3.4KN TENSILE

0.3KN COMPRESSION

2.2KN TENSILE

2.7KN COMPRESSION

0.17KN TENSILE

2.2KN COMPRESSION

VEHICLE CLEARANCE

20.3KN

24.4KN COMPRESSION AVERAGED TO 23.1KN PER TIE

11.7KN TENSILE AVERAGED TO 7.8KN PER TIE

REDUCED WORKING LIFT LEVEL TO BE MANAGED ON SITE

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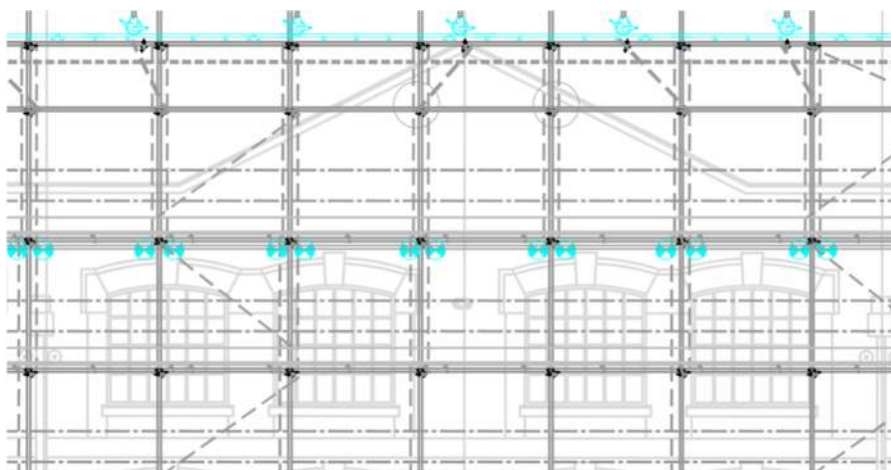


Figure 2-3 Typical tie locations at L2

2.2.2 Assessment Approach

With consideration to the building's historic significance and Grade II listing a systematic approach has been taken to carrying out analysis and assessing options for strengthening, with a clear preference to do as little as possible to the existing building fabric, if possible:

1. Interrogate scaffolding design to reduce/rationalise loads wherever possible, to minimise effect on building. This resulted in a significant reduction in tension loads (via the full use of the ratchet strap) and compression loads being averaged between bays to reduce from 3.4tons to 2.3ton.
2. Holistic assessment of existing structures for scaffold loads, with initial focus on primary load paths and relying on pragmatic assessments of historic fabric. These checks included assessing the masonry wall's ability to bend vertically and horizontally to distribute tie loads to stiff points in the structure, and assess the capacity of connections between the walls and floor/roof structures where lateral loads can be transferred into the building's main stability systems.
3. Consideration of alternate load paths – are there other less obvious ways to prove the structures may be OK? This primarily included looking at re-using the existing 1980s steel braces, plus valley purlins to resist the scaffold loads.
4. If the above are not successful in showing the structures are adequate, develop strengthening proposals. Several options were explored, all with a view to minimising impact on the existing fabric whilst responding to site limitations.

2.2.3 Assessment Outcomes

Full details of these assessments are included in a separate calculation package which will be submitted to building control for review. A summary of the findings is included below:

- Whilst the existing masonry walls themselves are broadly adequate to resist temporary scaffold loads, the connection between the walls and the structural diaphragm formed by the roof has only nominal capacity and cannot be shown to be able to transfer the required forces into the main building structure. There is a risk of damage to the building fabric if strengthening is not implemented at this connection. This means that strengthening is required.
- The existing 1980s steel braces have only limited capacity and so are not able to fully resist the scaffolding loads. They were clearly designed for modest loading under normal wind conditions only. A scheme to strengthen them to achieve the required capacities was included in the strengthening options.
- Adjusting the positions of ties between the scaffolding and the existing building is beneficial for reducing the impact of loads on the building.
- Walls below L2 are adequate to resist temporary scaffolding loads.

3 Proposed Strengthening Option

3.1 Summary

Once it was confirmed that some element of strengthening or temporary works would be required an optioneering exercise was undertaken to determine the most appropriate methodology. This assessment looked at several options for providing the required strengthening, from which a preferred option has been developed. The preferred option is a balance of practicality and minimising impact on the existing building fabric. The internal spaces of the New Warehouse are heavily constrained due to the presence of plant and equipment, and a commercial kitchen. Removing or reconfiguring this equipment would be prohibitively expensive and complex for the current works. This means that several more common methods for providing internal bracing are ultimately not feasible. See Figure 3-1.



Figure 3-1 Examples of heavily congested spaces along northern edge of New Warehouse, limiting strengthening options

3.2 Optioneering

Strengthening or temporary bracing could be achieved through several methodologies. Within each methodology several different implementations options are possible, i.e. a diagonal bracing methodology may include props down to the L2 floor, or up to the roof structure; or could be proprietary products or manufactured from timber on site.

To avoid repetition, three finalised options were presented to be reviewed with the design team and contractor. These were provided with discussion of the relative advantages. The optioneering sketch is included in Appendix B, with options summarised below:

- A. Diagonal propping from ties at head of window down to L2 floor. This would allow the previous tie positions at the head of the L2 windows to be retained, and then transfer these loads directly down to the L2 floor structure. This is a robust methodology, but would require damage to the L2 timber floors and is infeasible along the northern elevation due to the existing equipment.
- B. Installation of brackets which provide strengthened connection between the masonry wall and roof purlins. This option is more feasible to install as brackets are only local to the wall itself, although access is still challenging. Impacts on the existing fabric include 12mm fixings into the masonry, and bolts through the timber purlins.
- C. Use scaffolding to brace the existing 1980s steel braces. This option has the smallest impact on existing fabric but its implementation is likely infeasible due to the presence of plant/equipment and the various partitions which would all need to be breached.

All options include some element of impact to the existing fabric – typically via making fixings into the masonry and timber elements. However, the critical aspect was ultimately the feasibility of safely installing the required bracing or bracketry. Only option B was judged to be feasible to install by the contractor due to the significant spatial constraints.

3.3 Proposed Detail

The proposed strengthening detail (option B from the optioneering study) consists of installing steel brackets to the inside face of the masonry wall at roof level, to better connect the walls to the roof purlins. These will be required at all purlin positions – typically 7 no. per bay. The intent is that these brackets will be left in place permanently to both allow for future scaffolding and to provide additional robustness at this interface which is a common failure point for historic buildings. Full details of the proposals are included in Appendix A, with an extract shown in Figure 3-2 below. To account for dimension differences between valley purlins and other purlins, multiple bracket types are required, as covered in the proposal sketch. Brackets are to be painted red to match existing metalwork (see *design influence* section for further discussion).

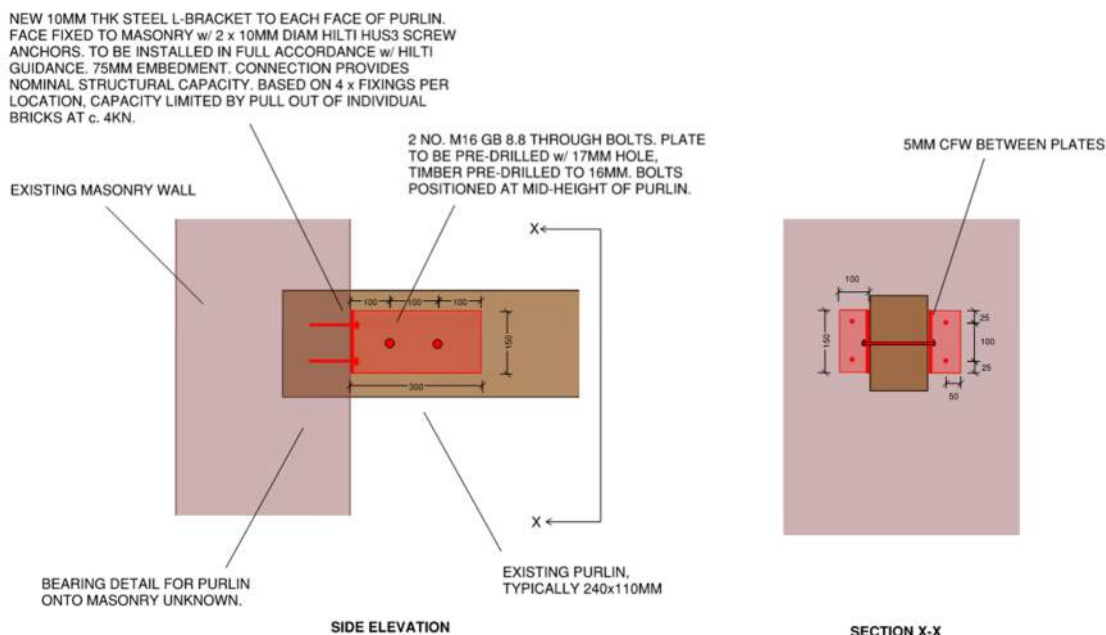


Figure 3-2 Proposal for strengthening brackets



Figure 3-3 Site mock-up of standard bracket detail (unpainted)

Design Influence

The design of proposed strengthening option has been heavily influenced by existing metalwork within the New Warehouse roof structure. There are at least three sets of similar metalwork present in the existing roof. Figure 3-4 to Figure 3-6 show these existing details:

- Cast iron nodes, brackets and tie bars which are part of the original 1870s roof trusses,
- Plated strengthening details to purlins and roof timbers, presumably from some time in the mid 1900s,
- A series of more modern steel braces and plates which are assumed to have been added in the 1980s when the museum took over stewardship of the New Warehouse building.



Figure 3-4 [left & right] 1980s steel bracing details, plus original cast iron truss nodes and ties beyond



Figure 3-5 [left] 1980s strengthening plate detail at roof valley positions. [right] 1980s plate & diagonal brace, plus earlier strengthening plate detail to valley purlin



Figure 3-6 [left] 1980s diagonal bracing arrangement. [right] 1980s plate/brace, plus earlier steel plate strengthening to underside of purlin, combined with timber scarf repair.

3.3.1 Mitigations / justifications

With consideration to the New Warehouse's historic status every effort has been made to justify the proposed loading without interventions, but this has proved to be infeasible. The following points are noted with respect to justifying and mitigating the proposals:

- The proposed roof replacement and fabric repairs are essential works to safeguard the building and conserve its character and fabric. These have been submitted and approved under separate LBC applications, but are relevant here as implementing those essential works is the root cause of the required scaffolding.
- The scaffolding is extremely constrained which necessitates the current design and the loadings applied to the New Warehouse building. To the north of the building a shared access road prevents a wide scaffold platform being constructed. On both north and south there is inadequate space to provide sufficient ballast to offset some of the loads from the temporary roof, which would be a common solution to this issue. This approach would also risk overloading the foundations and basement walls of both the New Warehouse and adjacent properties.
- The form and design of the proposed interventions has been carefully developed to reflect aspects of the existing building fabric – both original and from previous interventions throughout the building's history. Red-painted metalwork and strengthening details are common across the roof structure and the proposed details are in-keeping with this design language. They are intended to be honest and visible parts of the building's ongoing history and are reversible if required. All proposed connections are bolted and fixings into masonry are mechanical rather than resin-fixed to allow removal.
- Leaving the proposed bracketry in place following the completion of the current works should simplify future maintenance and/or conservation work to the New Warehouse by providing proven, engineered load paths for forces associated with scaffolding or other temporary works.
- Leaving the proposed bracket detail in place will also address an apparent pre-existing issue, namely concerns around the level of structural integrity at the head of the wall. The 1980s bracing suggests that there were concerns about the level or condition of the connection between the wall and the roof structure. This is a common failure point on historic buildings, and the proposed works will strengthen this interface and minimise any impact from future failure of the building fabric in this location. There is extensive evidence of water staining down the inside face of the gable walls, suggesting that this interface may have moved throughout the building's lifetime, affecting the flashing and allowing water to penetrate.

4 Appendices

- Appendix A – Sketch SK-S-0003 - Temporary loading assessment for New Warehouse scaffolding
- Appendix B - Sketch SK-S-0002 – Options for temporary works