

Corn Exchange, Manchester

Report on Structural Interventions required for Futureproofing for Upper Floor Change of Use

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1 Executive Summary

The purpose of this report is to summarise the structural works required to the lower floors to 'futureproof' the Corn Exchange building in Manchester, in order to allow the potential future change of use of the upper floors from their current office use to use as a hotel, without the need to carry out any works below second floor level following the completion of the current refurbishment of the lower retail floors. The document briefly consists of an introduction to the building and the currently proposed scheme to the lower retail floors, descriptions of the appraisal and analysis carried out to determine the structural implications of the potential change of use and the structural works that are required to the building up to 2nd floor level to 'futureproof' the building. A selection of sketches illustrating the key structural details are also included. A brief description of the implications on the below ground drainage is also presented.

In order to accommodate a change in intended use any new proposals (and affected areas of existing building construction) must meet current Building Regulations; specifically the requirements within Building Regulations part A1 (Loadings) and part A3 (Disproportionate Collapse) need to be achieved. This report details the findings of structural appraisal, analysis and studies carried out along with discussions held with Manchester City Council Building Control and their structural engineering department. The results of this analysis and discussions demonstrate that significant structural interventions, in the form of the introduction of additional horizontal and vertical tying to the existing structure are required to meet the requirements of part A3 (Disproportionate Collapse) of the Building Regulations.

In addition, whilst an initial structural appraisal and calculations carried out demonstrate that the majority of the existing 2nd floor structure can accommodate the imposed loading associated with the intended change of use, there are specific areas where floor strengthening and possibly stiffening will be necessary. It is important to note that this report does not specifically consider the existing condition of the structural elements forming the lower floors or the 2nd floor in particular, or any deterioration that has occurred during the life of the building. It is our understanding that dry rot may be present to the 2nd and 3rd floors to the Fennel Street elevation of the building, which may necessitate the replacement of areas of the existing floor structure, but the consequence of this is not at this moment known, and is outside the scope of this report.

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2 Introduction

The Manchester Corn Exchange is a Grade II mixed use building situated within the city centre between Exchange Square and Cathedral Gardens. The building was built between 1897 – 1903 and over time has seen many alterations. The detonation of the IRA bomb in 1996 caused extensive damage to the lower structure of the building, and major structural refurbishment and redevelopment took place between 1998 – 2000 to repair and reopen the Corn Exchange.

The upper four levels (2nd floor and above) currently serve as office space, and are in consideration for redevelopment by the client; with the intent of refurbishing the existing office space into a boutique hotel. The proposed change in use of the upper floors of the building requires an assessment of the robustness of the structure and a determination of its inherent ability to resist a collapse that is disproportionate in magnitude to its cause. In addition, the ability of the existing upper floors and supporting structure to accommodate the proposed change of use has also been assessed.

The structural assessment carried out has been based upon the existing and/or original structure as outlined in a number of archive drawings produced for the 2000 alterations, by Oscar Faber Structural Engineers. The set of drawings received by Buro Happold cover most of the internal cross wall elevations and the existing floor construction to the upper floors at that time. Certain assumptions have been made regarding the exact arrangement and layout of the structure in isolated locations where no archive information is available.

Intrusive structural surveys are currently being carried out to confirm the extent, size, strength and construction interfaces of the upper floors. The results of these structural surveys should be available by the end of February 2014.

In order to accommodate a change in intended use, Building Control require confirmation that any new proposals (including affected areas of existing building construction) meet current Building Regulations. To demonstrate that the structure is adequate the requirements within Building Regulations A1 (Loadings) and A3 (Disproportionate Collapse) need to be achieved. In addition Building Regulations B (Fire safety) and E (resistance to passage of sound) will have an impact on the structure due to the need for additional floor build-ups and protection which is likely to be required. Below ground drainage will also need to achieve the requirement of Building Regulations H1 (Foul water drainage).

From discussions with Building Control; where no change of use is proposed from when the works were undertaken in 1998-2000, no further justification is needed, and this is the approach that has thus far been taken regarding the refurbishment works to the lower three floors of the building. Where a change of use is proposed, Building Control need either a reasoned justification or detailed calculations to demonstrate that the building can safely accommodate the new super dead and imposed loads. Building Control also need to be satisfied that other building regulation requirements to resist disproportionate collapse are achieved.

This report presents the steps taken to meet the current Building Regulations in terms of robustness and loadings, for the lower floors and 2nd floor level, in order to ‘futureproof’ the building for the change of use of the upper floors to hotel use.

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2.1 Proposed Structural Scheme Overview

The centre is currently operating as a retail and restaurant development over the lower ground, upper ground and first floor levels. Office accommodation is provided over the upper floors, with access independent from the Mall.

Aviva Investors (owners) are proposing a remodelling of the centre to a food and beverage usage to the lower floors. As part of these proposals, various structural interventions are required, as described in the following sections.

The proposed structural works include;

- Structural infill of the internal ground floor atria space
- New glazed extensions to the Fennel Street elevation at ground floor
- General works to the lower ground and ground floors which include:
    - Floor level alterations to the ground floor
    - Re-grading of existing entrance ramps at ground floor
    - Escape stair extension at FS02/FS03 into lower ground floor/basement
    - Infilling of an existing void at 1st floor level
    - Formation of new service risers
- Works to the internal atria facing shopfronts
- New permanent canopies over the proposed entrances at ground floor level
- Futureproofing works up to and including the 2nd floor level, required to allow the change of use of the upper floor from office to hotel use without the need to carry out any works below second floor level following the completion of the current refurbishment of the lower retail floors

2.2 Existing Construction

The Corn Exchange building consists of three blocks arranged around a central atria with a domed roof. The current building was built in stages between 1897-1903 and is typically of load-bearing masonry façade and cross-wall construction (with occasional wrought iron beams and wrought or cast iron supporting columns) with a mix of timber and filler joist clinker concrete floors.

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Figure 1: Exposed cross wall and wrought iron structure during 1998-2000 refurbishment works

The original use was retail to basement, ground and first, with office use above. The building has undergone various structural alterations during its life with the most recent and intrusive being in 1998-2000 following the IRA bombing in 1996. For these works the basement was lowered and ground and first floors slabs completely removed and replaced with steel beams and concrete on composite metal decking. A number of the cross-wall foundations were also underpinned and various openings increased and/or introduced within the cross walls. The nature of the historic works means that every cross-wall has a different configuration of openings and interventions.

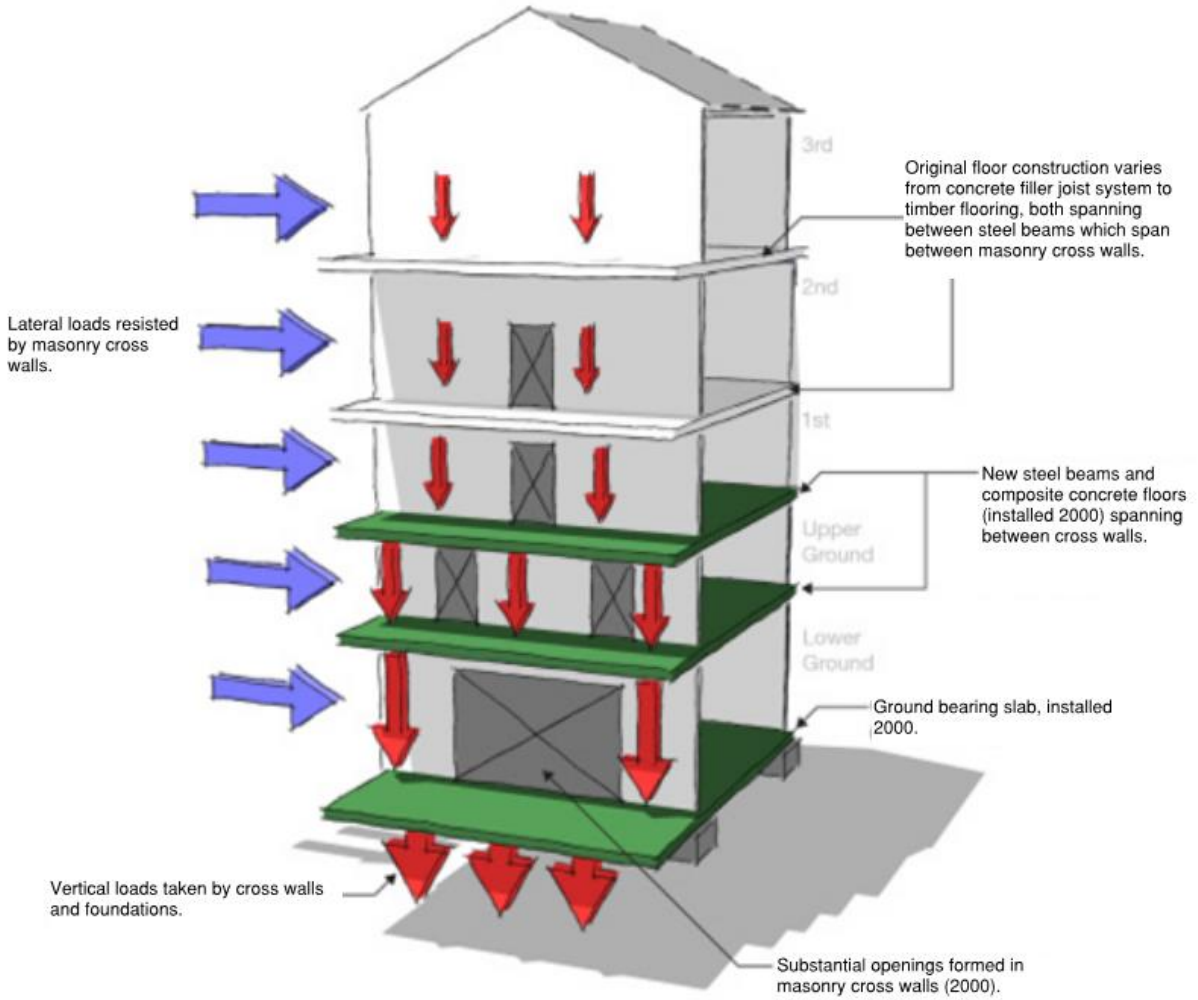


Figure 2: Structural principles and load path to the existing building

Due to the historical nature of the building, the existing structure consists of various forms of construction. The lower suspended floors (Lower Ground, Upper Ground and 1st floor levels) were generally replaced during the 2000 refurbishment works and consist of reinforced concrete on metal decking, acting compositely with supporting steel beams. These beams generally span between masonry cross walls or new or existing columns. The remaining upper (2nd – 5th) floors are typically a mixture of timber and clinker concrete filler joist floor construction. These elements span onto steel / wrought iron beams, which span onto masonry cross walls and cast iron columns, with the walls also assisting in the overall lateral stability of the building.

The second floor construction is of particular interest in the context of this report, given that this floor forms the proposed interface between the floors where no change of use is proposed and those where a potential change of use is proposed. The current second floor construction consists of a mixture of flooring types, including concrete filler joist slabs, timber joists floors, arched or 'vaulted' concrete floors and composite concrete metal deck flooring (Appendix A contains Oscar Faber drawing 17760/C/022 rev A, dated July 1998, which indicates the 'existing' second floor layout as presumably surveyed prior to the 1998-2000 refurbishment works).

3 Futureproofing Works and Considerations

3.1 Robustness and Resistance to Disproportionate Collapse

To determine whether the current building structure complies with the Building Regulations Approved Document A, the building must demonstrate sufficient robustness so as to ensure a disproportionate collapse cannot occur in the event of an accidental loading. To determine this, stipulations outlined in section A3 paragraph 5.1 of the regulations must be adhered to. The building has been identified as being a Consequence Class 2B building, and as such requires the consideration and application of the following guidance where relevant:

- **Option 1** - Performing a member check, whereby the designer checks that the removal of columns and notional lengths of load bearing walls (considered individually in turn) does not give rise to overall instability of the building structure. Furthermore, with each element removed, the total area at risk of collapse must be no more than 15% of the total floor area of that storey or 100m^2, whichever is smaller. The collapse area must also not extend further than the immediate adjacent storeys.
- **Option 2 -** If the removal of a structural member results in damage in excess of the above limits, the member may then be designed (or in this case checked) as a 'key element' as defined in section 5.3 of the regulations, where the element must be able to withstand a horizontal and vertical loading of 34kN/m^2 (considered separately).
- **Option 3 -** Alternatively, provide both horizontal and vertical ties in all supporting columns and walls to ensure a minimum capacity is achieved in accordance with the relevant material/construction standards.

In determining the latent robustness of the existing structure, a member check was performed that focused on each principle line of support (typically on each gridline) and removing either a column or length of wall (governed by the clear height of the storey) in turn to see how much of structure was at risk of collapse and the area of floor affected. It was assumed that no continuity is present in and between the existing timber joist and concrete filler joist floor, and masonry and studwork walls. The existing columns are typically formed of wrought or cast iron, and as such are assumed to bear end to end between storeys. In taking a fairly onerous approach for the purpose of this analysis, it has been assumed that no tensile capacity exists between the column splices. In this case, any inherent robustness available within the structural frame (such as via catenary action) has been disregarded.

Due to the typical method of construction of the building, the structural member to incur the greatest area of collapse was predominantly the load bearing masonry walls. In considering the amount of wall to be removed, a length of 2.25xH (where H is the clear height of the storey) was adopted, which in most cases resulted in a length of approximately 9m being removed.

The resultant floor areas expected to collapse per storey on the removal of a key element nearly all fell below the 100m^2 requirement. The one exception to this was within the Fennel Street wing where the floor area per storey at risk of collapse reached a maximum of 105m^2 on the removal of a 9m wide run of wall at lower ground floor level along gridline FS/07.

Whilst the removal of key elements almost entirely results in an area at risk to collapse below the required maximum, the majority of cases resulted in a progressive failure mechanism, whereby storeys in excess of those adjacent to the storey of the removed element would be likely to collapse. As such, we were *unable* to satisfactorily demonstrate that the current building structure complies with the Building Regulations Approved Document A, as the removal of columns and notional lengths of load bearing walls would give rise to overall instability of the building structure.

As a result of this, the approach of checking the existing key elements within the structure that govern this behaviour under accidental loading was considered. As the building has an existing gas supply, both elements were checked using the nominal 'gas explosion' value of 34kN/m^2 which is applied both horizontally and vertically in turn to the element being analysed. Whilst the cast iron column may be able to resist the blast load requirements, an assessment on the masonry cross walls indicated the element fails under this loading. As such, we could *not* satisfactorily demonstrate that key elements of the structure were able withstand a horizontal and vertical load of 34kN/m^2.

Whilst this theoretical exercise suggests that additional tying is required, an alternative argument may be made in that the structure has been tested in a 'real world' catastrophic accidental loading scenario (the 1996 IRA bombing), where the building was able to resist the onset of a disproportionate collapse under the blast loading from 1,500kg[1] of high explosives in close proximity to the structure. In light of this empirical evidence, the view may be taken that it may be justified to accept that the building will not fail in a disproportionate manner with respect to the magnitude of its cause due to the past performance of the structure under exceptional real world conditions.

This argument was presented to the Structural Engineer from Manchester City Council Building Control, and whilst the logic presented was accepted, the empirical evidence presented was not considered compelling enough to allow Building Control to waive the requirement to demonstrate sufficient robustness of the building in strict accordance with part A3 of the Building Regulations.

The only remaining course of action allowable in accordance with Part A3 of the Building Regulations is the introduction of horizontal and vertical ties in all supporting columns and walls to ensure a minimum capacity is achieved in accordance with the relevant material/construction standards. Due to the varied construction materials used in the construction of the building, reference was made to the following British Standards:

- BS 5268 : Part 2 : 2002 Structural use of timber. Code of practice for permissible stress design, materials and workmanship (incorporating Amendment No. 1).
- BS5628: 1992 Code of Practice for Use of Masonry.
- BS 5950: Part 1: 2000 Structural Use of Steelwork in Buildings.
- BS 8110: Part 1: 1997 Structural use of concrete. Code of practice for design and construction.

Using guidance contained in the British Standards outlined above, and considering the existing floor and supporting wall constructions the following outline arrangement of horizontal and vertical ties has been developed.

[1] [1] Lesser, Ian; Hoffman, Bruce; Arquilla, John; Ronfeldt, David; Zanini, Michele (1999), *Countering the New Terrorism*, Rand, ISBN 0-8330-2667-4

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3.1.1 Horizontal Ties

The exact location and arrangement of the horizontal tie beams will be determined in conjunction with the architect and based upon the existing floor construction. According to the relevant British Standards both *internal* and *perimeter* ties are generally required, and each tie much be capable of resisting appropriate axial forces. As a general approach the internal ties are required approximately centrally to the floor plates. The following outline the general tying approach proposed considering the existing floor construction at each level.

- Lower Ground Floor – no additional *internal* tie beams proposed to the majority of the new steel framed floor, although tie connections will be necessary between existing beams where no continuity is present (for instance over internal loadbearing walls where beams are supported on individual padstones). *Perimeter* ties necessary to tie existing masonry piers where no new steel beams introduced in the 1998-2000 works or where no original steel beams of sufficient size are present, although as with the internal ties, tie connections will be necessary between existing beams where no continuity is present .
- Upper Ground Floor – no additional *internal* tie beams proposed to the majority of the new steel framed floor, although tie connections will be necessary between existing beams where no continuity is present (for instance over internal loadbearing walls where beams are supported on individual padstones). *Perimeter* ties necessary to tie existing masonry piers where no new steel beams introduced in the 1998-2000 works or where no original steel beams of sufficient size are present, although as with the internal ties, tie connections will be necessary between existing beams where no continuity is present .
- First Floor - no additional *internal* tie beams proposed to the majority of the new steel framed floor, although tie connections will be necessary between existing beams where no continuity is present (for instance over internal loadbearing walls where beams are supported on individual padstones). *Perimeter* ties necessary to tie existing masonry piers where no new steel beams introduced in the 1998-2000 works or where no original steel beams of sufficient size are present, although as with the internal ties, tie connections will be necessary between existing beams where no continuity is present .
- Second Floor – no additional *internal* tie beams will generally be required to the majority of the existing floor, given that there are generally original spine beams spanning between the loadbearing cross walls and beams. As with the lower floors, however, additional tie connections will be necessary between existing beams where no continuity or insufficient continuity is present (for instance over internal loadbearing walls where beams are supported on individual padstones). Additional *perimeter* tie beams will be necessary to tie the existing external masonry piers as the vast majority of the original perimeter steelwork consists simply of lintel beams, which have no continuity through the piers.

3.1.2 Vertical Ties

Vertical ties will generally consist of 10mm thick flat plates or varying width at various centres, which will be introduced to tie successive floors to one another. Ties will be introduced to each of the loadbearing cross-walls, or to elements of the supporting wrought iron and wrought or cast iron supporting columns; both of which are generally located on the gridlines. The exact arrangement of the vertical ties depends upon the exact arrangement, form and construction of the floors and the exact arrangement, form and construction of the loadbearing cross-wall or supporting steel or iron framework. In general, however, the ties will be at approximately 4m centres, and located so that they connect directly between floor beams to each successive floor.

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3.1.3 Proposed Tying Details

A selection of the tying details proposed is presented in Appendix B, including the interface required between the horizontal tie elements and vertical tie elements.

3.2 Change of Use and Floor Loadings

Buro Happold have carried out a desk top study to compare the proposed imposed floor loadings to the proposed upper floors, corresponding to the intended use of the buildings, and the imposed loading that the floors are likely to have been designed to accommodate originally. In addition, an initial structural appraisal of the load carrying capacity of the existing floors has been carried out.

This desk study and initial appraisal has allowed us to assess whether the existing floors are likely to be adequate for the proposed change of use and to confirm the extent and general form of any floor strengthening required.

3.2.1 Current Imposed Loading Requirements

The current British Standard on the subject of imposed floor loadings is BS 6399: Part 1: 1996. This standard defines an imposed load as “the load assumed to be produced by the intended occupancy or use, including the weight of movable partitions, distributed, concentrated, impact and inertia, loads, but excluding wind loads”. In effect, an imposed load is any load carried by the structure that is not an integral part of the building. This document then outlines recommended minimum imposed loads for use in designing buildings, which apply to new buildings; alterations and additions to existing buildings and the change of use of existing buildings and structures.

The minimum imposed loads outlined are those appropriate to the type of activity or occupancy for which the floor will be used in service. The types of activity covered include:

A. Domestic and residential activities
B. Office and work areas
C. Areas where people may congregate
D. Shopping areas
E. Areas susceptible to the accumulation of goods
F. Vehicle and traffic areas

As such, new buildings are designed to accommodate a consistent and accepted imposed load allowance, based upon the use of the floor. In addition, alterations to existing structures must be shown to be capable of supporting an appropriate imposed load, again based upon the use of the floor.

The categories of floor use appropriate for the redevelopment of the upper floors of the Corn Exchange are outlined below (extract from Tale 1 BS 6399: Part 1: 1996):

Type of activity/occupancy for part of the building or structure	Examples of specific use	Uniformly distributed load kN/m^2	Concentrated load kN
A Domestic and residential activities	All usages within self-contained single family dwelling units Communal areas (including kitchens) in blocks of flats with limited use (See note 1) (For communal areas in other blocks of flats, see C3 and below)	1.5	1.4

Type of activity/occupancy for part of the building or structure	Examples of specific use		Uniformly distributed load kN/m^2	Concentrated load kN
	Bedrooms and dormitories except those in single family dwelling units and in hotels and motels		1.5	1.8
	Bedrooms in hotels and motels Hospital wards Toilet areas		2.0	1.8
	Balconies	Single family dwelling units and communal areas in blocks of flats with limited use (See note 1)	1.5	1.4
		Guest houses, residential clubs and communal areas in blocks of flats except as covered by note 1	Same as rooms to which they give access but with a minimum of 3.0	1.5/m run concentrated at the outer edge
B Offices and work areas not covered elsewhere	Offices for general use		2.5	2.7
	Balconies		Same as rooms to which they give access but with a minimum of 4.0	1.5/m run concentrated at the outer edge
C Areas where people may congregate **C1 Areas with Tables**	Public, institutional and communal dining rooms and lounges, cafes and restaurants (See note 2)		2.0	2.7
	Reading rooms with no book storage		2.5	4.5
C3 Areas without obstacles for moving people	Corridors, hallways, aisles, stairs, landings etc. in institutional type buildings (not subject to crowds or wheeled vehicles), hostels, guest houses, residential clubs, and communal areas in blocks of flats not covered by note 1. (For communal areas in blocks of flats covered by note 1, see A)	Corridors, hallways, aisles etc. (foot traffic only)	3.0	4.5
		Stairs and landings (foot traffic only)	3.0	4.0
	Corridors, hallways, aisles, stairs, landings, etc. in all other buildings including hotels and motels and institutional buildings	Corridors, hallways, aisles, etc. (foot traffic only)	4.0	4.5
		Corridors, hallways, aisles, etc., subject to wheeled vehicles, trolleys etc.	5.0	4.5
		Stairs and landings (foot traffic only)	4.0	4.0
	Balconies (except as specified in A)		Same as rooms to which they give access but with a minimum of 4.0	1.5/m run concentrated at the outer edge
C5 Areas susceptible to	Assembly areas without fixed seating, concert halls, bars		5.0	3.6

Type of activity/occupancy for part of the building or structure	Examples of specific use	Uniformly distributed load kN/m^2	Concentrated load kN
overcrowding (See clause 5, Note 1, Note 2 and Note 3)	and places of worship (See Note 4)		
E Warehousing and storage areas. Areas subject to accumulation of goods. Areas for equipment and plant.	Reading rooms with book storage, e.g. libraries	4.0	4.5
	General storage other than those specified	2.4 for each metre of storage height	7.0
	Plant rooms, boiler rooms, fan rooms, etc., including weight of machinery	7.5	4.5

This table is quite involved, and outlines all the expected or possible uses within the building. The majority of the floor areas are to house hotel, office, bar/dinning and plant room use and we would propose that the following imposed loads be adopted for these areas:

Proposed floor usage	Uniformly distributed load kN/m^2	Concentrated load kN
Bedrooms in hotels and motels	2.0	1.8
Corridors, hallways, aisles, stairs, landings, etc. in all other buildings including hotels	4.0*	4.5*
Office	2.5	2.7
Bar and lounges	5.0	3.6
Library	4.0	4.5
Plant rooms	7.5**	4.5**

* assuming no wheeled vehicles, trolleys etc.
**if the actual weight of the plant equipment, fixings and fittings is known this can usually be adopted in lieu of a blanket load of 7.5kN/m2.

In addition to the above, clause 5.1.4 of BS 6399: Part 1: 1996 notes the following:

5.1.4 Partitions
When permanent partitions are indicated, their weight should be included in the dead load, acting at the given partition location.
In buildings where the use of other partitions is envisaged, an additional imposed load should be specified for the floor area. This may be taken as a uniformly distributed load of not less than one third of the load per metre run of the finished partitions. For floors of offices, this additional uniformly distributed partition load should not be less than 1.0 kN/m^2.

It is therefore common practice to include and allowance for lightweight partitions of 1.0kN/m^2. As such, the general imposed load that the upper floors will be required to support is 2.0 + 1.0kN/m^2. It is not common practice to add an allowance for lightweight partitions of 1.0kN/m^2 to circulation areas (corridors), bar/dining areas, libraries and plant rooms.

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3.2.2 Original Imposed Loading

Unfortunately, no statutory guidance similar to BS6399 was published before the 1909 London Building Act, and as the Corn Exchange was fully constructed prior to 1909, we cannot simply refer to any statutory documents, that were in existence when the building was designed, to assess the original imposed loading.

There was loading advice given in various textbooks and these were often used to determine appropriate imposed loading. The figures quoted in textbooks published at the end of the 19th century and the beginning of the 20th century varied greatly but typical imposed loads ranged between 3.0 to 5.0 kN/m^2 for offices, 6.0 to 17.0 kN/m^2 for warehouses and 10 to 24 kN/m^2 for floors housing heavy machinery. One of the major steelwork manufacturers of the time, Dorman Long, suggested in guidance published in 1895, imposed loading of 3.8 kN/m^2 for offices and dwellings, 5.7 to 15.3 kN/m^2 for warehouses and 10.5 to 20.1 kN/m^2 for heavy machinery.

As outlined, the 1909 London Building Act did specify minimum imposed loads on floors. Those relevant to the Corn Exchange include a minimum loading of 4.8 kN/m^2 for office floors. Whilst it is clear that the figures quoted in this document will not have been used in the original design of the Corn Exchange, the values quoted do indicate the approximate loading used around this time.

Considering the above references, the likely imposed loading used in the design of the upper floors to the Corn Exchange are likely to have been between 3.0 to 5.0 kN/m^2 for offices. A summary of the imposed loads suggested in various literature at the turn of the 19th and 20th centuries is included within Appendix A.

In addition to the above approach, it is telling that the current use of the upper floors is general office space, with circulation to the corridors, and the current British Standard imposed load requirements for office space is 2.5kN/m^2, with an allowance for partitions of no less than 1.0kN/m^2. When combined this imposed load allowance is greater than the current imposed load allowance outlined as relevant to bedrooms in hotels and motels which is 2.0kN/m^2. As such, it could be argued that in general the floors have already been 'load tested' to a magnitude greater than anticipated for the proposed future use. A similar argument could be made for the current circulation areas, including the corridors, where the required imposed load allowances to BS6399 do not change with a change of use from office to hotel.

The exception to this is areas where it is proposed to house bar/dining, reception and lounge areas over the main staircase at 2nd floor level (between gridlines HD/07 and HD/12 along the Hanging Ditch elevation) and a library to the 3rd floor. The imposed load requirements stated within BS6399 for a dining area is actually 2.0kN/m^2, but it is noted in BS6399 that *"Where these same areas may be subjected to loads due to physical activities or overcrowding, e.g. a hotel dining room used as a dance floor, imposed loads should be based on occupancy C4 or C5 as appropriate"*, as such the imposed loading relevant to these areas is more truthfully that relevant to bar areas, which is 5.0kN/m^2.

3.2.3 Initial Structural Appraisal

Structural appraisal is a check on the adequacy or capability of an existing structure to continue to support its own self weight and any imposed loads. An initial structural appraisal of the existing 2nd floor structure has been carried out to inform the likely structural strengthening required at this level.

Discussion with the Engineers who undertook the 1998-2000 alteration works have taken place and this indicates that they designed the lower intervention works (to the lower ground, upper ground and first floor primarily) to support an imposed load of 2.5 + 1.0kN/m^2 to the offices and as specified in the Developers Brief elsewhere (generally 5.0kN/m^2). They also confirmed the upper floors to be a mix of timber and filler joist and clinker concrete floors, which has subsequently been confirmed during the ongoing opening up works. Due to the high void ratio within the clinker concrete they confirmed that the upper floor slabs where grouted during the 1998-2000 alteration works. In addition, floor panel test result on three floor samples removed from the lower floors where undertaken in 1997 and are included in the Operation & Maintenance Manual. Unfortunately the samples were not tested to destruction; and a back analysis from the specified Safe Working Load determined, is not sufficient to demonstrate that the clinker floors can accommodate 2.0 + 1.0kN/m^2 loading. A single sample was tested to 100kN with no signs of distress, and when back analysed this would justify a residual imposed load capacity of at least 3.6kN/m^2 for the single sample tested.

In addition, an appraisal of the existing filler joist floor was carried out (assuming continuity over supports) was also undertaken to BD21/93 (*Department of Transport et al. Highways Agency. The Assessment of highway bridges and structures. BD 21/93. London: DTp, 1993*) which suggested an approximate imposed load capacity of 3.89kN/m^2. This is based on the steel filler joist sizes and spacing from the lower floor slab sample above, and will be reviewed against the results of the ongoing opening up works being carried out.

No information is yet available on the size, strength and condition of the upper timber floors, and hence the exact imposed load capacity of the structure cannot be assessed at this stage. Opening up and survey works are currently being carried out which should allow us to carry out and appraisal of the loadbearing capacity of the existing timber joists.

3.2.4 Conclusion

Following a review of the 'historic' loading requirements, and an initial appraisal of the extant floor structure, it seems reasonable to conclude that the filler joist, clinker concrete floor and its supporting structure can support an imposed load of circa 2.0 + 1.0kN/m^2. No information is yet available on the size and layout of the timber floors, and hence the exact imposed load capacity cannot be assessed but it would be safe to assume at this stage that the loadbearing capacity of the timber joists will be similar to that of the clinker floors, and would be able to support a similar imposed loading. Consequently Buro Happold do not propose that any general floor strengthening will be required to the upper floors where they house hotel rooms, and where areas of circulation are being maintained (such as to the existing corridors).

Unfortunately, there is no evidence to suggest that any of the existing floors or the existing supporting structure has been design to support an imposed load of 5.0kN/m^2, and as such there is no evidence to suggest that the existing floors will be strong enough and/or stiff enough to support the imposed loads associated with and required in accordance with BS6399 for bar/dining and lounge areas. In addition, with the exception of areas currently housing plant, there is no evidence and nothing to suggest that the upper floors have been designed to support or will be capable of supporting plant loading of 7.5kN/m^2.

As such, it is very likely that additional strengthening of these areas of the 2nd floor will be required. The strengthening required is likely to take the form of one or more of the following:

- Additional supporting steelwork to reduce the spans of the clinker concrete, filler joists or timber joists
- Strengthening of the supporting floor beams with the introduction of additional steel plates, angles and/or channels.

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- Removal of existing floor finishes and the replacement with lighter material to reduce the dead weight (i.e. the removal of a screed finish and the introduction of a timber raised floor).

It is important to re-iterate at this point that the assessment presented in this report does not consider the effects of any deterioration to the structural elements which may have occurred and there are areas of floor that may need to be repaired or replaced due to corrosion and/or fungal attack (it is our understanding that there are areas of the Fennel Street elevation for instance that are currently the subject of investigations in to the possibility of dry rot). The strengthening or replacement that may be required purely due to any deterioration of any structural elements is outside the scope of this report.

In addition to the above strengthening options there is also an option to limit or restrict the use of specific areas of the floor in the future. This is particularly relevant to the proposed reception area at 2nd floor level directly over the main entrance staircase. Given the preceding discussion, it is likely that this area may need to be strengthened to be able to support the imposed load associated with a reception area (although a detailed appraisal of the existing floor in this area is currently being carried out). Unfortunately, it may prove very difficult, if not impossible, to strengthen the existing floor structure in this area from below, given that the supporting beams and floor slab are currently encased in ornate and what appears to be original plasterwork, which would be difficult to remove and reinstate properly and without affecting original features of the building. It may be possible to strengthen this section of floor from above, but this will only be confirmed following the detailed structural appraisal being carried out.

In addition to the above discussion regarding the load carrying capacity of the upper floors, the dynamic performance of the upper floors will need to be assessed, primarily in terms of floor vibrations and user comfort. Older structures and particularly timber floors tend to have a reputation as being 'bouncy', and whilst this may be appropriate for the current office use, it may not be deemed acceptable for hotel rooms. The vibration characteristics of a floor are measured in terms of the anticipated acceleration of the floor subject to a stimuli (generally footfall), and is quantified in terms of a response factor, R, where a lower figure represents lower acceleration values, and therefore a less vibrant floor. For Hotel and Residential use where there is the potential for people to be sleeping adjacent to an area where people may be walking a response factor, R, of between 2 and 4 is usually appropriate to reduce the risk of occupier complaint. In contrast, the response factor, R, currently specified to office floors is approximately 8. As such, it is very likely that some additional stiffening of the 2nd floor level will be required, regardless of the load carrying capability of the floor. This is, however, likely only to be required to the timber floors, as the generally high mass of the filler joist clinker floors has a dampening effect on the floor vibration. The stiffening required is likely to take the form of one or more of the following:

- Additional supporting steelwork to reduce the spans of the timber joists;
- Stiffening of the floor with the introduction of additional timber joists, or by the introduction of additional strutting or noggins between joists;
- Replacement or over-sheeting of the existing floorboards with 'structural' plywood that is glued and screwed to the existing joists.

3.3 Below Ground Drainage

The current above ground drainage is limited to three main cores and is associated with office use. The total foul water flow from the offices is relatively small. Changing the use of the upper floors to Hotel use will increase the foul water flows, which will have an impact on the existing below ground drainage system, which in areas is likely to have insufficient capacity.

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Work will be carried out in conjunction with the above ground drainage designer to limit the impact of this increased foul water flow on the proposed below ground drainage, but it is anticipated that areas of existing drainage will need to be either upsized and/or re-laid to greater falls.

It has been confirmed by United Utilities that we have the right to discharge foul water and surface water (unrestricted) to the sewer network from the premises. As such, no attenuation of surface or foul water is required or proposed.

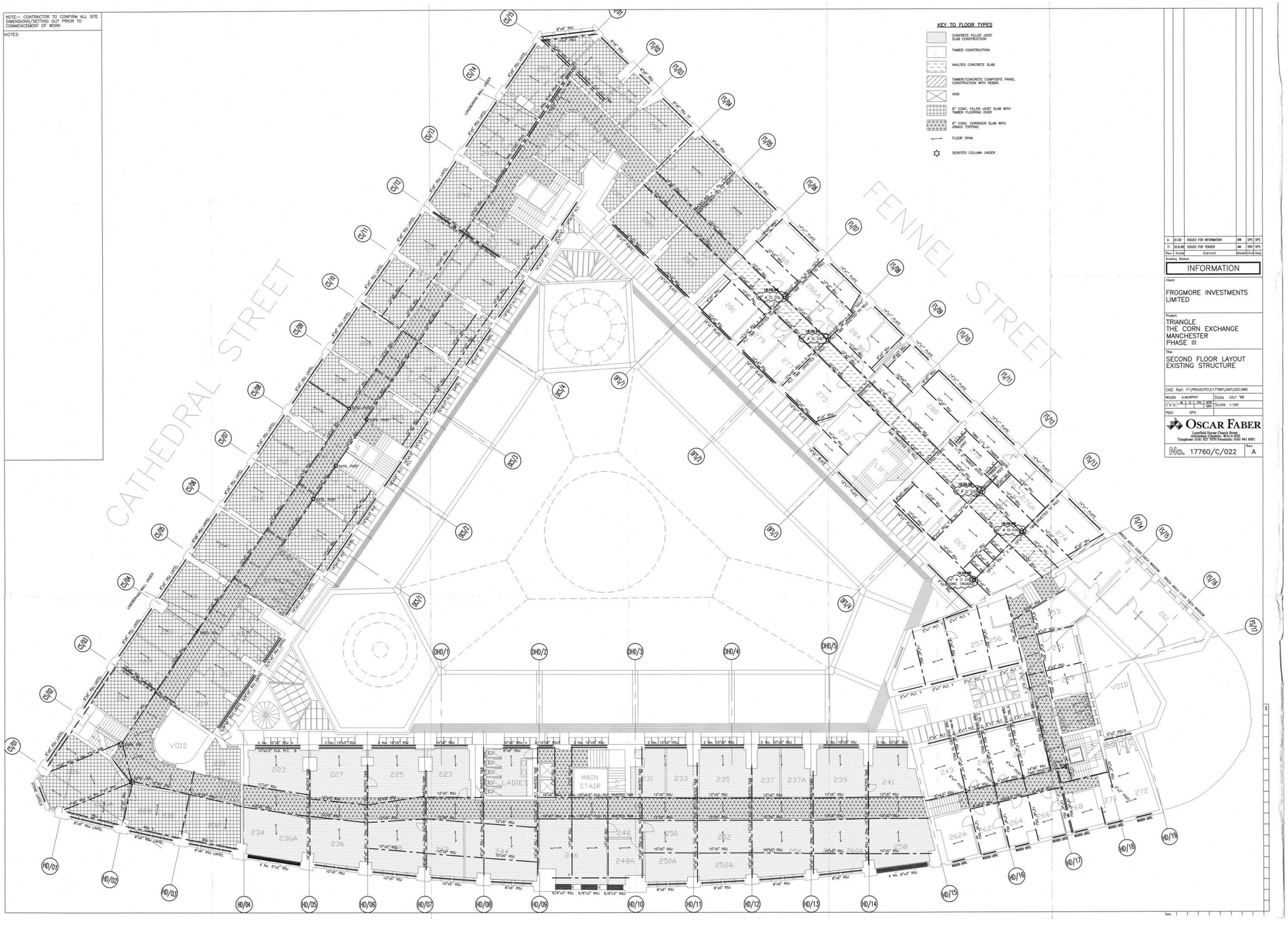
4 Civil and Structural Futureproofing Proposals

Following a detailed appraisal of the current robustness of the Corn Exchange building (including various discussions with Manchester City Council Building Control department) and following an initial appraisal of the structural capacity and likely loadbearing capacity of the upper floors, Buro Happold propose the following civil and structural works be carried out the lower ground, upper ground, first and 2nd floor levels of the Corn Exchange to futureproof the structure for the potential change of use of the upper floor from office to hotel use:

- ***Robustness and Resistance to Disproportionate Collapse***: Provide horizontal and vertical tying at all levels up to 2nd floor, and introduce additional horizontal and vertical tying to existing steelwork and ironwork where required.
- ***Change of Use and Floor Loadings***: Strengthening of the 2nd floor structure where the proposed use and imposed loading requirements (according to BS6399) are greater than the floor either currently supports or will have likely been designed to support. This is generally limited to the area between gridlines HD/07 and HD/12 along the Hanging Ditch elevation of the building.
- ***Occupier Comfort***: Stiffening to the existing timber floors with the introduction of additional timberwork, or by the replacement of the existing floor boarding with a structural element.
- ***Below Ground Drainage***. Upsizing and/or the relaying of areas of existing drainage to greater falls, to accommodate increased foul drainage flows.
- ***General Structural Works***. Including the introduction of additional and larger risers within the floors to accommodate additional services required for the hotel; introduction of additional vertical circulation to various floors (exact extent to be confirmed).

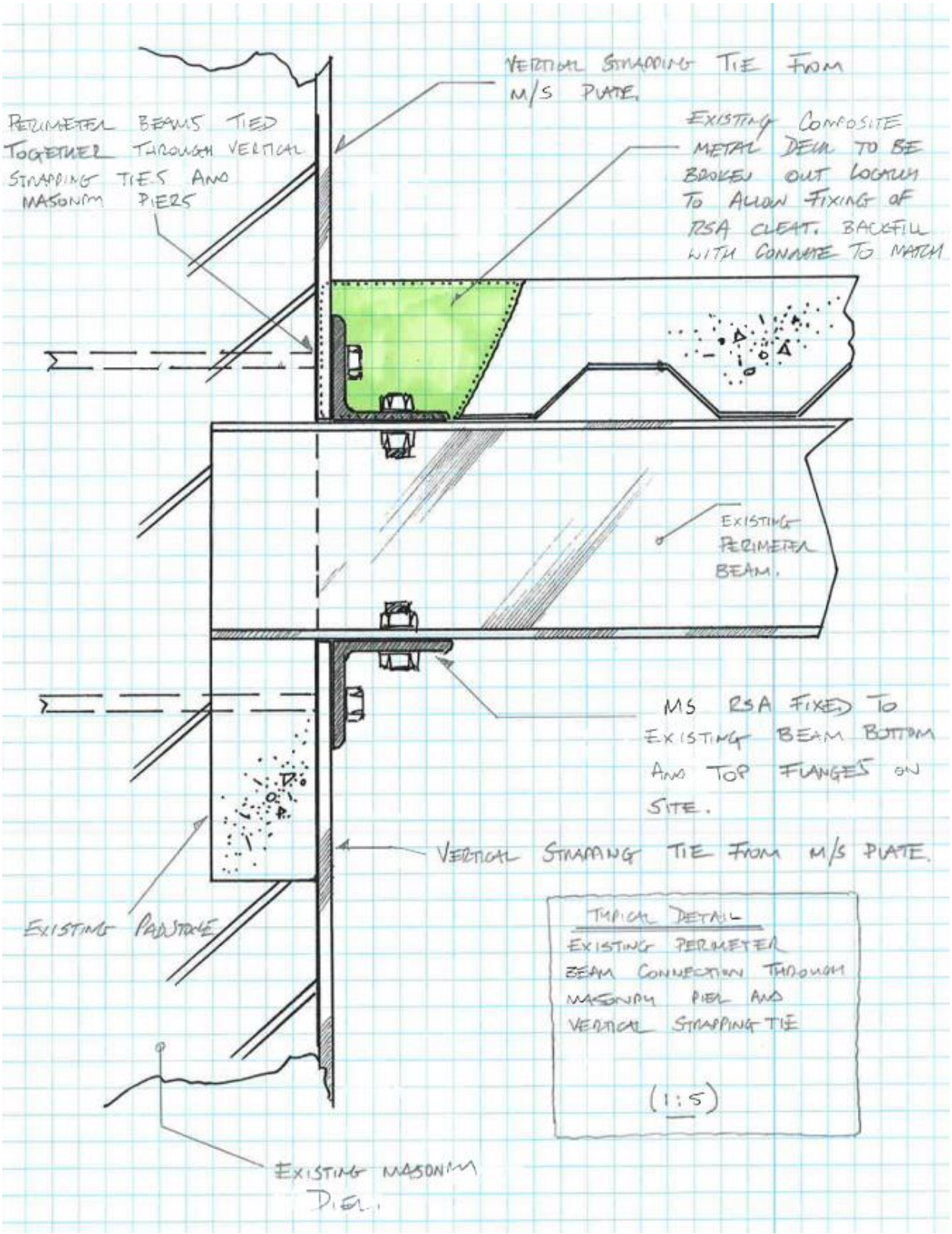
Appendix A – Oscar Faber Existing Second Floor Layout Drawing

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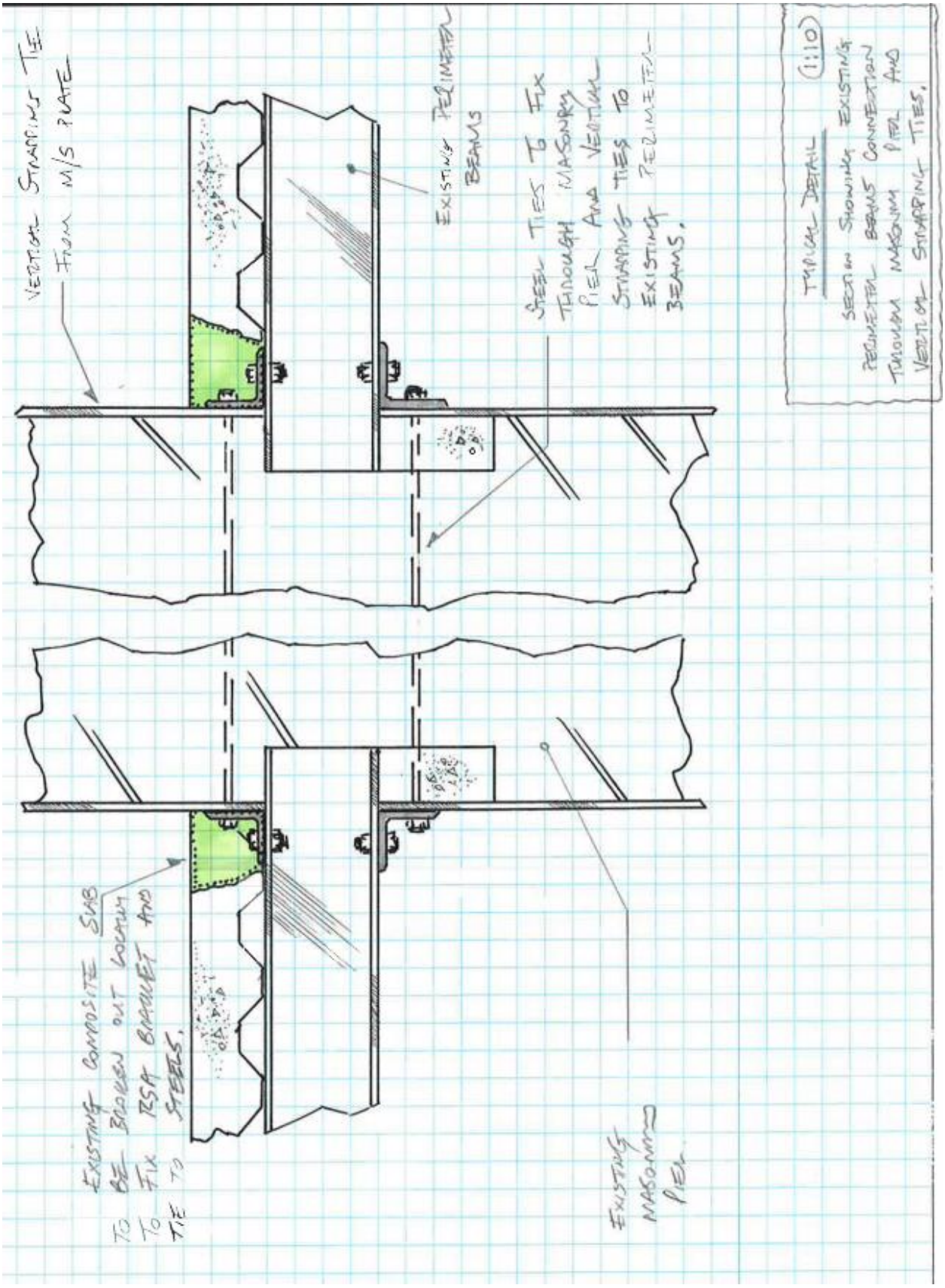


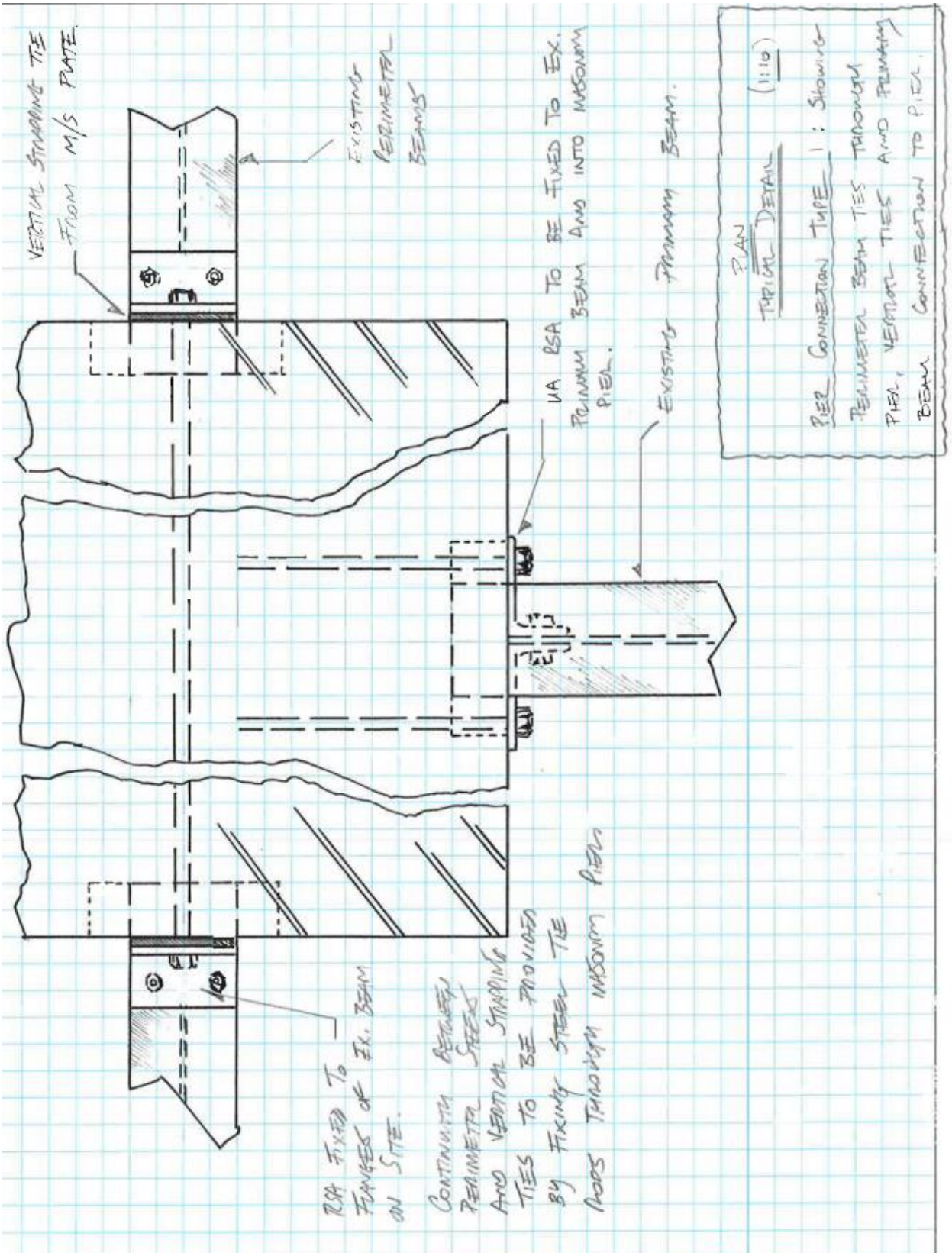
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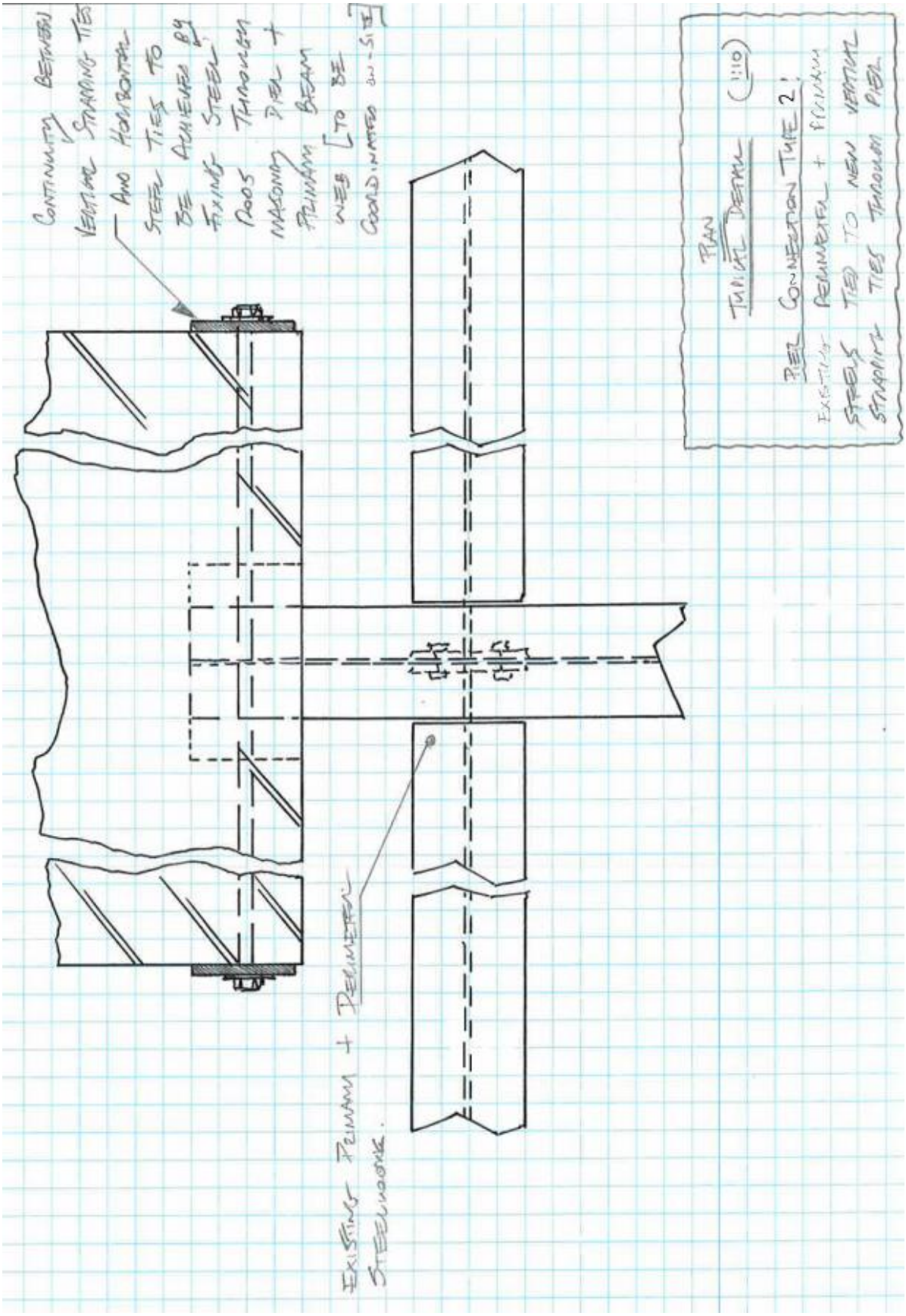
Appendix B – Typical Tying Details



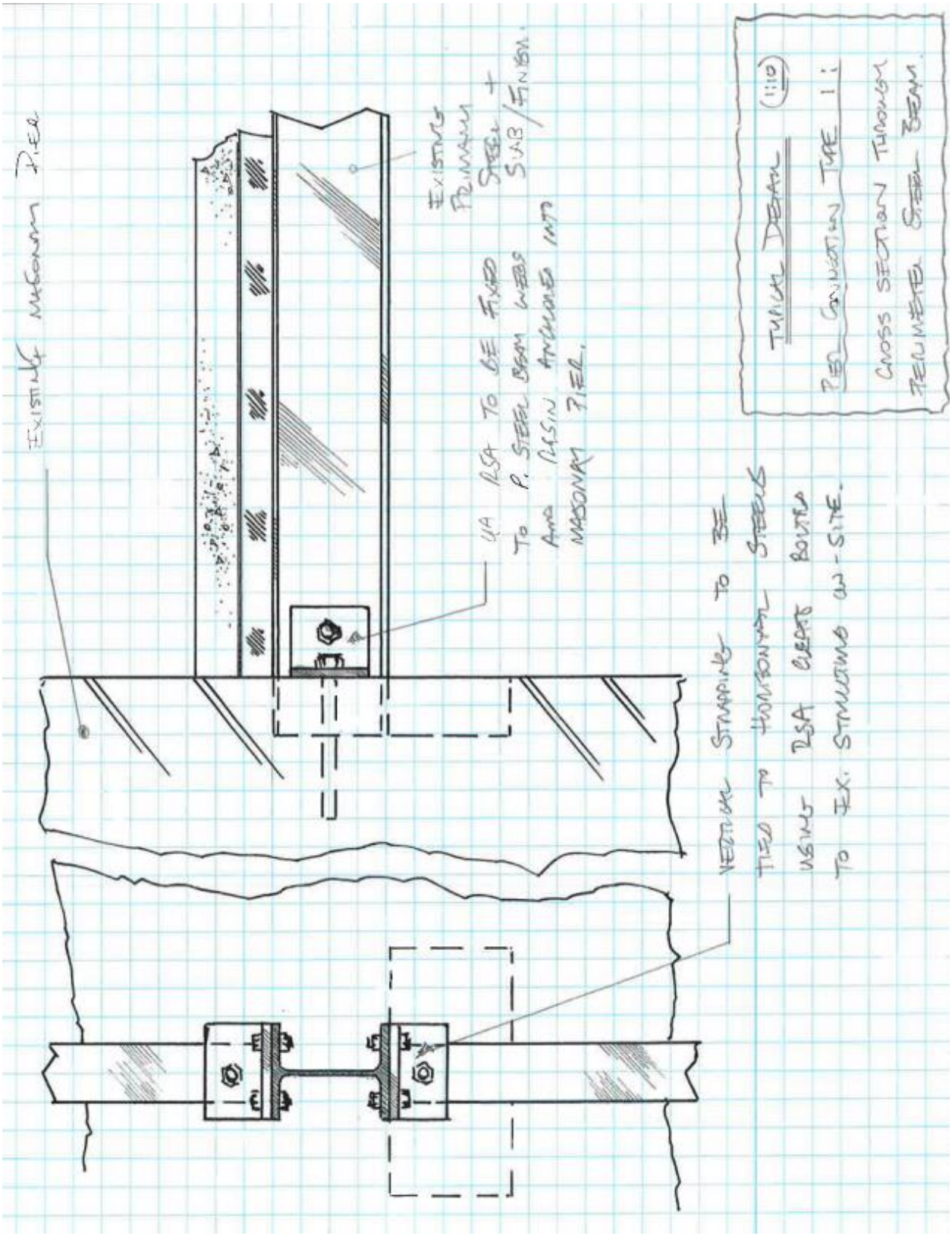
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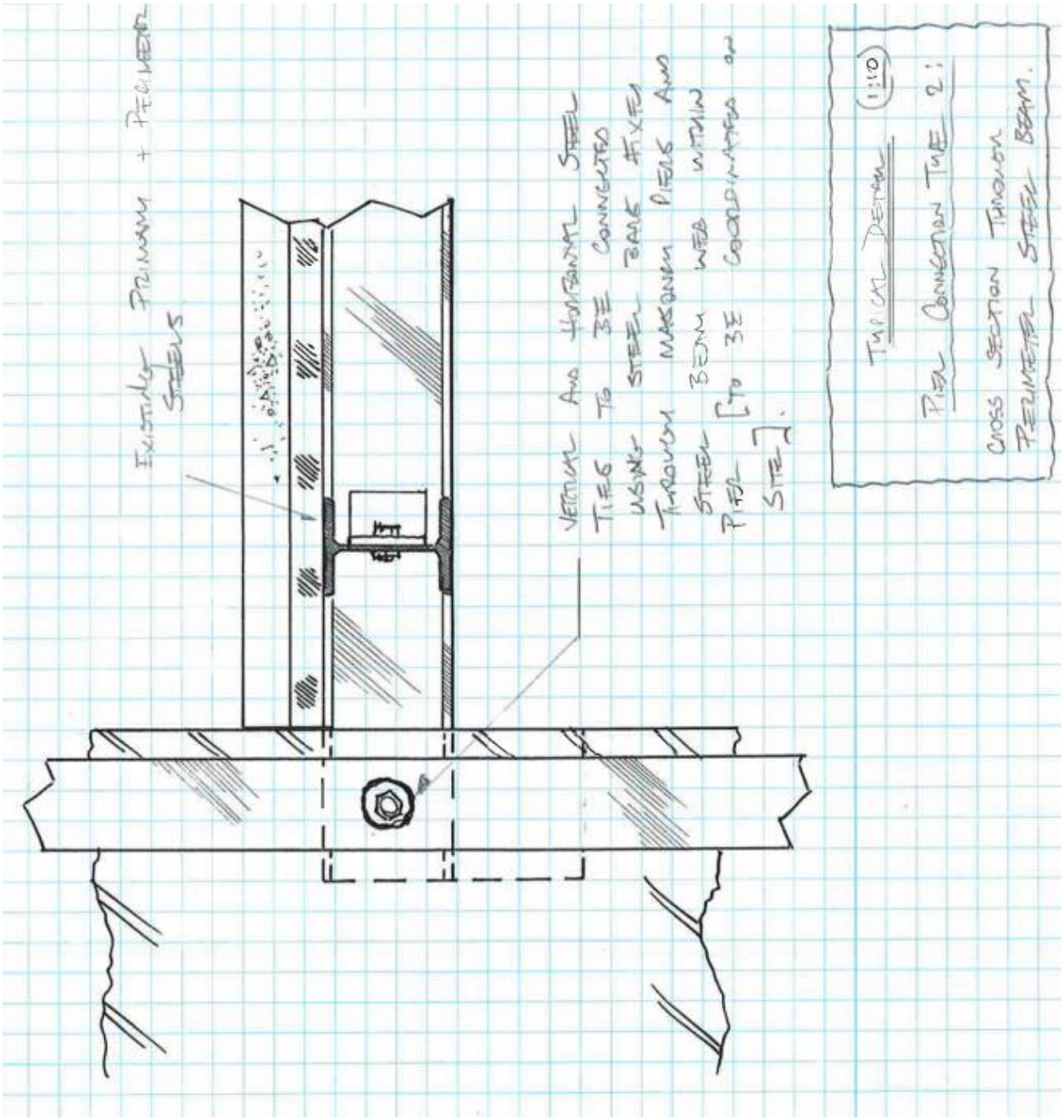

VERTICAL STRAPPING TIE FROM M/S PLATE
EXISTING PERIMETER BEAMS
STEEL TIES TO FIX THROUGH MASONRY PIER AND VERTICAL STRAPPING TIES TO EXISTING PERIMETER BEAMS.
EXISTING COMPOSITE SUB BEAM
TO BE BROKEN OUT LOCALLY TO FIX RSA BRACKET AND TIE TO STEELS.
EXISTING MASONRY PIER
TYPICAL DETAIL (1:10)
SECTION SHOWING EXISTING PERIMETER BEAMS CONNECTION THROUGH MASONRY PIER AND VERTICAL STRAPPING TIES.


VERTICAL STRAPPING TIE FROM M/S PLATE.
EXISTING PERIMETER BEAMS
UA 85A TO BE FIXED TO EX. PRIMARY BEAM AND INTO MASONRY PIER.
EXISTING PRIMARY BEAM.
PLAN
TYPICAL DETAIL (1:10)
PIER CONNECTION TYPE 1 : SHOWING PERIMETER BEAM TIES THROUGH PIER, VERTICAL TIES AND PRIMARY BEAM CONNECTION TO PIER.
UA 85A FIXED TO FLANGES OF EX. BEAM ON SITE.
CONTINUITY REINFORCED STEELS AND VERTICAL STRAPPING TIES TO BE PROVIDED BY FIXING STEEL TIE RODS THROUGH MASONRY PIER

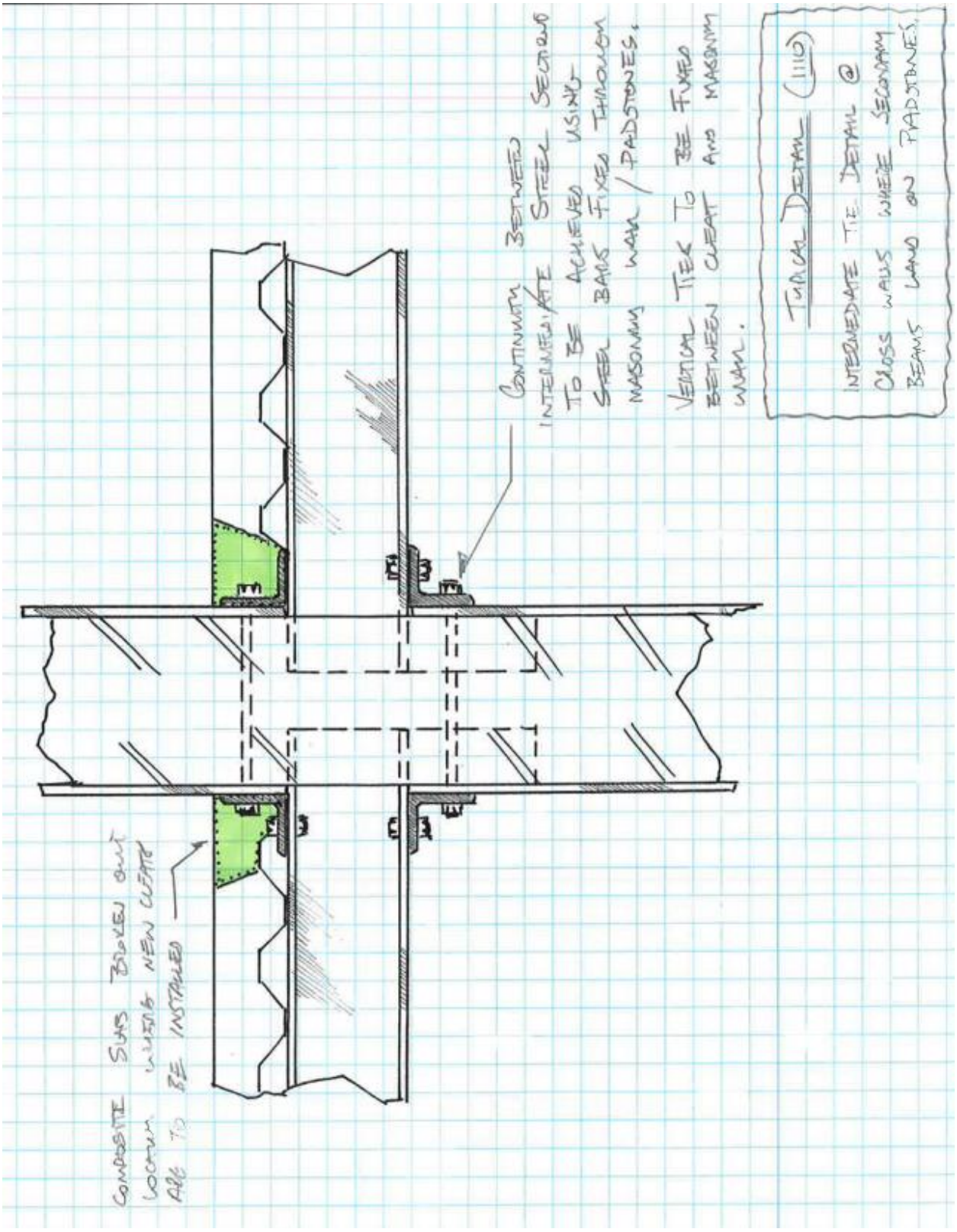


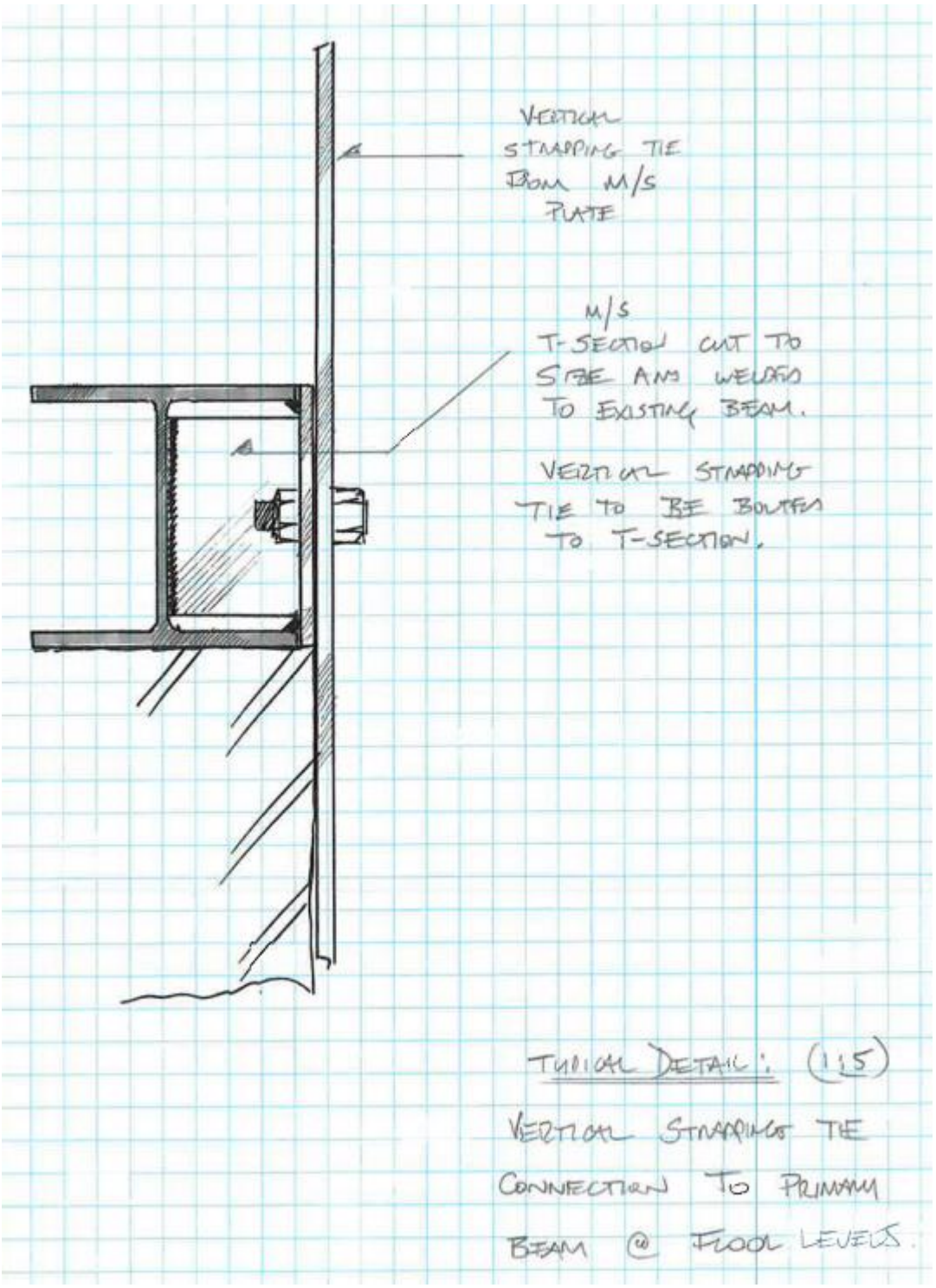
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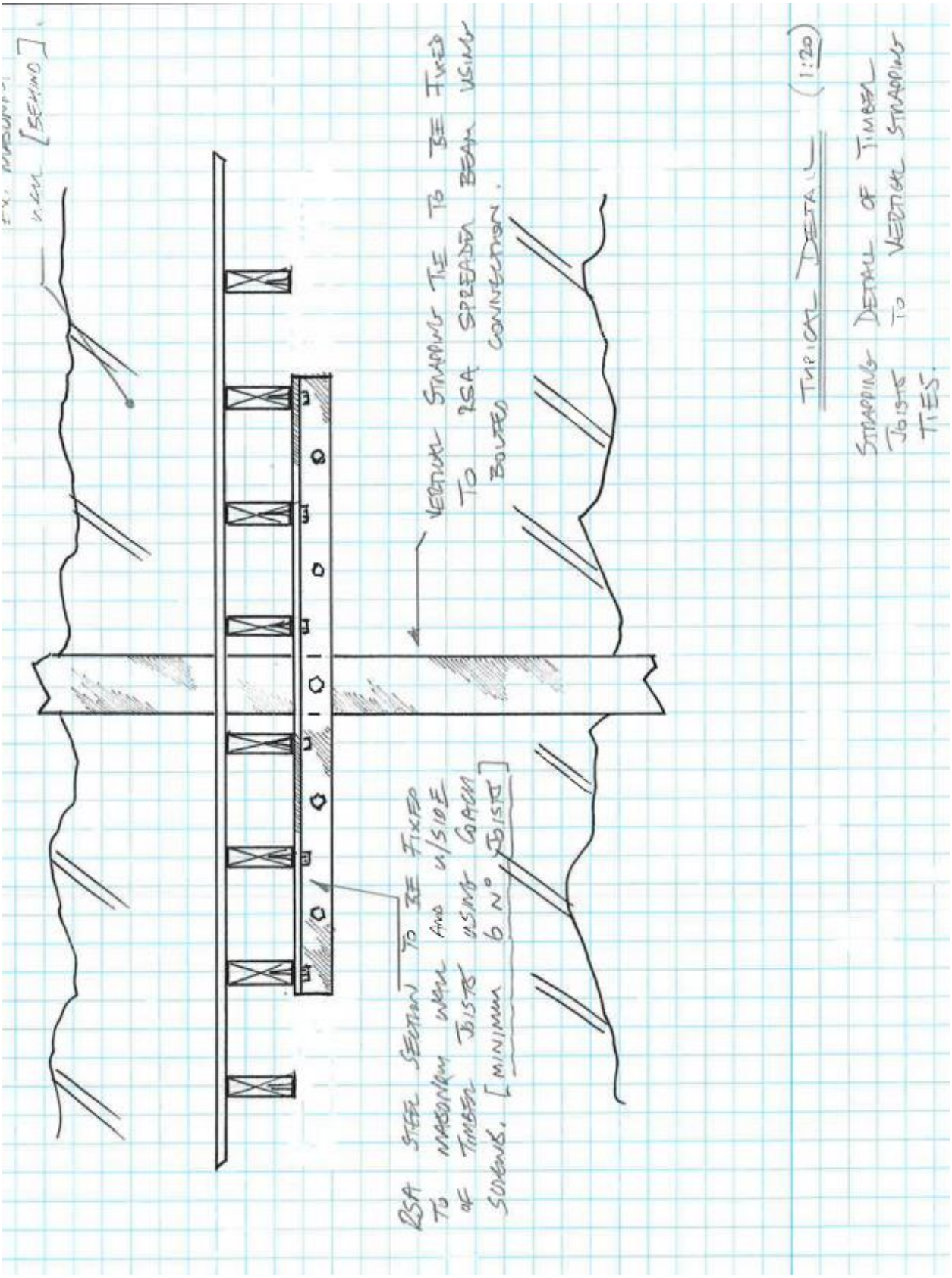

EXISTING MASONRY P.E.R.
EXISTING PERIMETER STEEL + SLAB/FINISH.
UA RSA TO BE FIXED TO P. STEEL BEAM WEBS AND CASIN ENCASED INTO MASONRY P.E.R.
VERTICAL STRAPPING TO BE TIED TO PERIMETER STEELS USING RSA BRACKETS BOLTED TO EX. STRUCTURE AS-SITE.
TYPICAL DETAIL (1:10)
P.E.R. CONNECTION TYPE 1:
CROSS SECTION THROUGH PERIMETER STEEL BEAM



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CONTINUOUS BETWEEN STEEL SECTIONS INTERMEDIATE TO BE ACHIEVED USING STEEL BARS FIXED THROUGH MASONRY WALL / PADSTONES.
VERTICAL TIES TO BE FIXED BETWEEN CONCRETE AND MASONRY WALL.
TYPICAL DETAIL (1110)
INTERMEDIATE TIE DETAIL @ CROSS WALLS WHERE SECONDARY BEAMS LAND ON PADSTONES.
COMPOSITE SLABS BROKEN OUT LOCALLY WHERE NEW OPENS ARE TO BE INSTALLED


VERTICAL STRAPPING TIE FROM M/S PLATE
M/S T-SECTION CUT TO SUBE AND WELDED TO EXISTING BEAM.
VERTICAL STRAPPING TIE TO BE BOLTED TO T-SECTION.
TYPICAL DETAIL: (1:5)
VERTICAL STRAPPING TIE CONNECTION TO PRIMARY BEAM @ FLOOR LEVELS.


VERTICAL STRAPPING TIE TO BE FIXED TO 25A SPREADER BEAM USING BOLTED CONNECTION.
25A STEEL SECTION TO BE FIXED TO MASONRY WALL AND U/SIDE OF TIMBER JOISTS USING 6mm Ø SCREWS. [MINIMUM 6 No JOISTS]
TYPICAL DETAIL (1:20)
STRAPPING DETAIL OF TIMBER JOISTS TO VERTICAL STRAPPING TIES.

Appendix C – 'Historical' Imposed Loading Advice

Encyclopaedia of Architecture (first published 1842)

- Light workshops and factories, public halls and churches and other buildings in which people only accumulate, with warehouses for light goods - 128lbs/sq ft (6.1 kN/m^2)
- Storehouses for heavy goods 240lbs/sq ft (11.5 kN/m^2)
- Ordinary dwelling houses 100lbs/sq ft (4.8 kN/m^2).

Dorman Long and Co Handbook 1895

- Dwellings or Office Buildings – 80lbs/sq ft (3.8 kN/m^2)
- Public Halls or Schools – 110lbs/sq ft (5.3 kN/m^2)
- Warehouses – 120 to 320lbs/sq ft (5.7 to 15.3 kN/m^2)
- Heavy Machinery – 220 to 420lbs/sq ft (10.5 to 20.1 kN/m^2)

Appleby's Handbook of Machinery 1903

- Attic Floors – 34 to 56 lbs/sq ft (1.6 to 2.7 kN/m^2)
- Dwelling room floors – 56 to 70 lbs/sq ft (2.7 to 3.4 kN/m^2)
- Offices, libraries etc. – 70 to 80 lbs/sq ft (3.4 to 3.8 kN/m^2)
- Stairs and passages – 80 to 90 lbs/sq ft (3.8 to 4.3 kN/m^2)
- Work rooms, light business premises etc. – 90 to 100 lbs/sq ft (4.3 to 4.8 kN/m^2)
- Churches, theatres, ballrooms, public halls, stores etc – 100 to 125 lbs/sq ft (4.8 to 6.0 kN/m^2)
- Workshops and light warehouses – 125 to 150 lbs/sq ft (6.0 to 7.2 kN/m^2)
- Warehouses for heavy materials – 150 to 400 lbs/sq ft (7.2 to 19.2 kN/m^2)
- Heavy machinery – 250 to 500 lbs/sq ft (12.0 to 23.9 kN/m^2)

London County Council (General Powers) Act 1909

- Clause 18(A) of section 22 of the act gave the following requirements for imposed loads:
- For a floor intended to be used wholly or principally for the purposes of human habitation or for domestic purposes - 70 lbs/sq ft of floor area (3.4 kN/m^2)
- For a floor intended to be used wholly or principally for the purpose of an office or a counting house or for any similar purpose - 100 lbs/sq ft of floor area (4.8 kN/m^2)
- For a floor intended to be used wholly or principally for the purpose of a workshop or retail shop - 112 lbs/sq ft of floor area (5.4 kN/m^2)

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- For every floor in a building of the warehouse class not intended to be used wholly or principally for any of the purposes aforesaid not less than 224 lbs/sq ft of floor area (10.8 kN/m^2)

In every building of the warehouse class a notice shall be exhibited in a conspicuous place on each storey of such building stating the maximum superimposed load per square foot which may be carried on the floor of such storey.

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