Quinan Stove
Royal Gunpowder Mills
Waltham Abbey

Structural Engineering Report

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Project No	612
Rev	Final
Date	8 December 2017

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1. Introduction

Stand Consulting Engineers were appointed by the Royal Gunpowder Mills to prepare a structural engineering report on Quinan Stove. This report gives a summary of the existing structure, its condition and recommendations for remedial work to extend its life.

This report is based on our review of a copy of record drawings held by the Royal Gunpowder Mills, the book 'The Listed Buildings and Other Principal Structures at the Royal Gunpowder Mills Waltham Abbey' by Les Tucker, our visual assessment of the structure seen during our visit on 4 September and our knowledge from previous projects with historic buildings including those built in the twentieth century. No intrusive investigations or tests have been carried out to date.

Gunpowder production on the site began in the 1660s. After it was taken over by the Crown in 1787 it became a centre for the research and development of explosives and the manufacturing continued until the Second World War. The site closed in 1991.

Quinan Stove, together with the majority of the buildings on the site, is designated as a Scheduled Monument.

The building is approximately aligned north-south and for the purposes of this report the main elevation is taken as east.

2. The site and summary of the existing structure

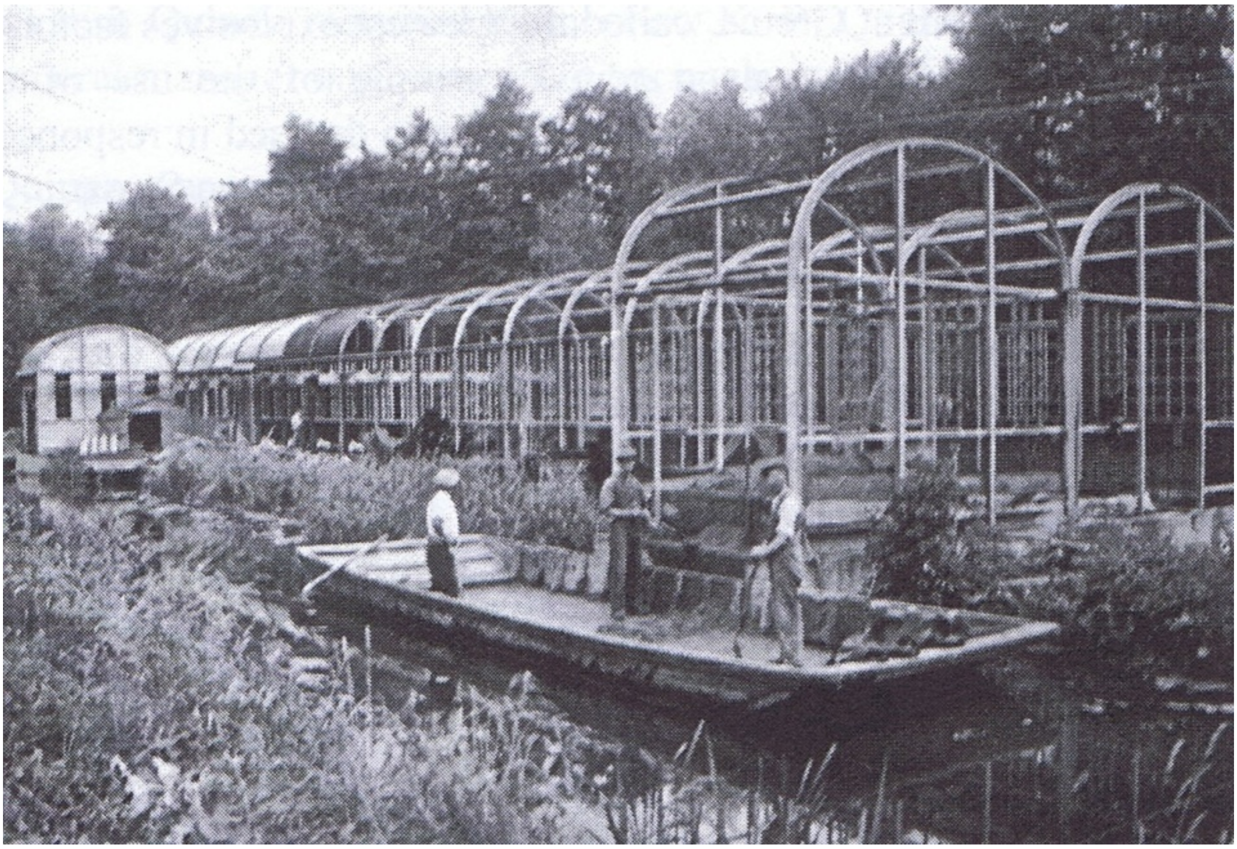
The site is adjacent to the Lee River and the underlying ground is made of river deposits of clay, silt, sand and gravel.

In 1895-6 a factory for the production of nitroglycerine was built in the north part of the site to meet the increased demand for cordite. Manufactured guncotton was transported by barge to the main site where it was dried in stoves and then mixed with nitroglycerine to produce cordite.

Quinan Stone was named after K. B. Quinan who became Head of the Explosives Supply Department in 1915. Drying of guncotton was a hazardous process and Quinan developed methods for the safe, rapid drying of small amounts of guncotton. The building, as shown on 1934 drawings, is laid out with 15 small bays that are separated by reinforced concrete walls. The walls were lined with painted calico to allow for the removal of dangerous cordite dust. These walls also contribute to the overall stability of the building.

The record drawings show the building is supported on 12” by 12” (300 mm square) driven, pre-cast reinforced concrete piles. Reinforcing bars protrude from the top of each pile to connect to 2’ 9” (838 mm) deep concrete ground beams below the perimeter of the building. These beams support a 9” (225 mm) thick reinforced concrete slab and the steel frame that forms the superstructure.

The steel frame is formed of pairs of 4” x 3” (100 x 75) stanchions that were bent to form the curved profile of the roof. These are arranged at 7’ (2134 mm) centres to form the drying bays with a double frame at each end. The stanchions are shown to be encased 27” (685 mm) into the top face of the ground beams. This provides a rigid connection so that the frame is self-stable during the construction, as shown on the historic photograph (image 1). The frames are connected together with two levels of horizontal, small-section steel angles up to the underside of the windows, a steel channel at the top of the walls and four lines of T-section steel purlins at roof level.



1. Construction during 1935 (from Tucker)

The walls are formed with 2½" (63 mm) thick reinforced concrete panels with a white cement: sand render on the outside face to give an overall thickness of 3" (75mm). The reinforcement is steel laths with ribs to provide a greater stiffness. There were many proprietary reinforced concrete systems available in the first half of the twentieth century and at least two manufacturers produced similar ribbed lath sheets; "Hy-Rib" by the Trussed Concrete Steel Co., Ltd and "Self-Sentering" manufactured by the Self-Sentering Expanded Metal Co., Ltd. Extracts of thee systems from a 1932 publication are below.

The curved roof slab is noted on drawing 22/4 dated May 1934 as "pumice concrete" and "reinforcement not to be fixed to T's". Pumice was used in place of normal aggregate to reduce the weight of the concrete. If there was an accidental explosion the blast would remove the lightly fixed roof and limit damage to the overall structure. The roof is covered with an asphalt finish.

A summary of the structure is shown on drawing SK 1.

2. Detail of the ribbed lath wall at window cill level. The horizontal angle has completely corroded

3. Detail of wall construction

1. The weights generally used in reinforced concrete work are as follows :—

Price List No.	Size of Mesh short way of diamond. Inches.	Dimensions of Strands. Inches.	Approximate Weight per yd. super. Lbs.
69	3	$\frac{1}{2} \times \frac{1}{4}$ bare.	30
68	3	$\frac{1}{2} \times \frac{3}{16}$,,	$22\frac{3}{4}$
30	3	$\frac{3}{8} \times \frac{3}{16}$,,	$17\frac{1}{4}$
31	3	$\frac{1}{4} \times \frac{1}{4}$,,	$15\frac{1}{4}$
62	3	$\frac{5}{16} \times \frac{3}{16}$,,	$14\frac{3}{4}$
10	3	$\frac{1}{4} \times \frac{3}{16}$,,	$11\frac{1}{2}$
61	3	$\frac{5}{16} \times \frac{1}{8}$,,	$9\frac{1}{2}$
11	3	$\frac{3}{16} \times \frac{3}{16}$,,	$8\frac{1}{2}$
8	3	$\frac{1}{4} \times \frac{1}{8}$,,	$7\frac{1}{2}$
9	3	$\frac{3}{16} \times \frac{1}{8}$,,	$5\frac{3}{4}$
15	3	$\frac{1}{8} \times \frac{1}{8}$,,	$3\frac{3}{4}$
7	3	$\frac{1}{4} \times$ 16G ,,	$3\frac{3}{4}$
67	3	$\frac{3}{16} \times$ 16G ,,	$2\frac{3}{4}$

The lighter weights of the $\frac{3}{4}$-in. and $1\frac{1}{2}$-in. Diamond Meshes are frequently used in concrete for encasing steelwork.

2. Hy-Rib (Fig. 6), manufactured by the Trussed Concrete Steel Co., Ltd., is made from very best quality British steel sheets, and owing to the rigid stiffening ribs which are raised in the material during manufacture, far less framing is required in the body of the building. This metal lathing is fashioned to turn and ease the plaster into a good key without wasting any material. Sheets are supplied in all lengths up to 12 ft., the standard width of sheets being $10\frac{1}{2}$ in. Outer ribs are made to interlock, so that any desired width can be built up. The sheets also overlap at ends, and in this way any desired height is attained. Hy-Rib is supplied in three gauges: 28, 26 and 24 gauge. For floor work, in addition to being supplied straight to rest on any type of beam, Hy-Rib can be supplied curved to fit between the lower flanges of rolled steel joists. Hy-Rib does away with the necessity for any close-boarded shuttering or timber centering; and the concrete flows through the lath of the material sufficiently only to give a good key for plastering the underneath surface. By using Hy-Rib, walls and partitions, which are strong, light, and fire-resisting may be quickly erected, with the additional advantage that such walls need only be from $1\frac{3}{4}$ in. to $2\frac{1}{2}$ in. thick. Similar advantages are gained in the case of suspended ceilings, boundary walls, tanks, reservoirs, culverts, etc. Hy-Rib is used in conjunction with fine concrete for lining steel chimneys and steel bunkers, and also for the rapid construction of balcony terracing in cinema, theatre, and sports stands. (See also under "Flooring" Systems.)

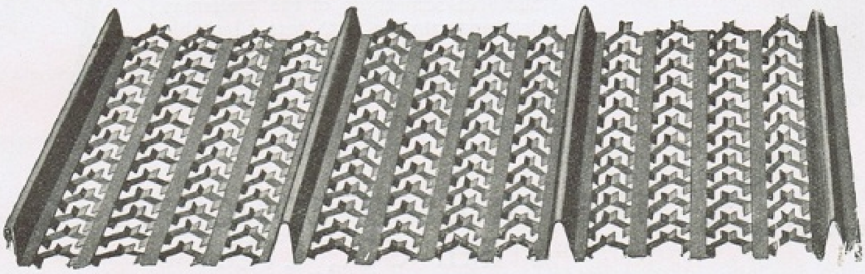


Fig. 6.—**Hy-Rib.**

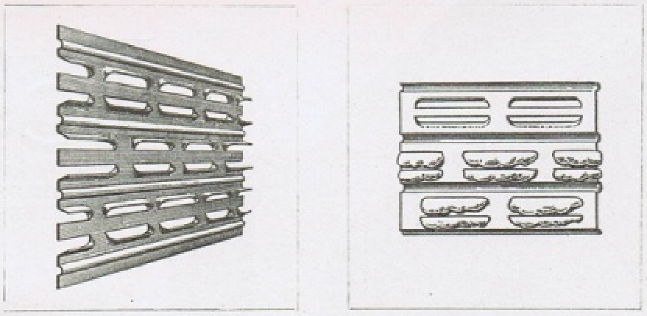


Fig. 7.—**"Jhilmil" Steel Lathing.**

3. "Jhilmil" is a steel lathing system, the material being made in sheets 72 in. by 24 in., and 72 in. by 18 in., which are easily cut. It is claimed that, owing to the special nature of the perforations, only the minimum of plaster passes through to act as key, and is supported, giving maximum saving of plaster together with strength and fireproofness. Various patterns are adapted respectively: (1) For wrapping round girders and columns, and for fixing on the rough wood of planking, etc.; (2) for bridging over spaces, as for ceilings, and (3) for partitions. The diagram on the left of Fig. 7 shows the stiffening ribs and the lips for the support of the plaster key, while that on the right indicates the lath partly plastered. Further reference to "Jhilmil" will be found in the "Proprietary Materials" section.

4. B.R.C. fabric (Figs. 21 and 22, p. 213) is a wire mesh made up of a series of parallel longitudinal wires held at fixed distances apart by means of transverse wires arranged at right angles to the longitudinal ones and securely welded to them at the points of contact by a patent electrical process. The steel wire is of the highest grade, having a tensile strength from 80,000 to 110,000 lb. per sq. in., and an average elastic limit of 75,000 lb. per sq. in. The safe tensile strength may be taken at 25,000 lb. per sq. in.

"Hy-Rib" by the Trussed Concrete Steel Co., Ltd

2. "Self-Sentering"—which is also manufactured by the Self-Sentering Expanded Metal Co., Ltd.—is a ribbed type of expanded metal made from specially selected steel sheets, the ribs being connected by diamond mesh expanded steel, as shown in Fig. 9. This material is largely employed in modern practice for a variety of purposes, including floors, roofs, tanks, sewers, culverts, air-ducts, and the like. Among the principal claims made for it by the makers, are: the speed with which it can be erected; the economy in timber, form work, and centering effected by its use, and the consequent elimination of skilled labour. Further particulars of its many applications will be found under "Flooring Systems."

3. "Double-mesh Herringbone" is a steel lath expressly designed for use with all kinds of plaster work, and is manufactured by the Self-Sentering Expanded Metal Co., Ltd. In its width it contains thirteen intermediate ribs (*see* Fig. 10), which are bent at a small angle to the main plane during the process of manufacture, and considerably augment its strength and stiffness. These ribs are connected together by small, flattened, and slightly twisted metal filaments, the whole being so arranged as to form a herringbone pattern. It is stated by the makers that a marked economy may be effected by the use of this lath, both in plaster and supports. The flattened filaments already referred to act as miniature baffle-plates, and allow only just sufficient plaster to pass through the mesh, and at the same time to curl over behind them, and thus form a particularly efficient key and protection to the metal. The lath is thus completely covered on the key side by the ordinary pressure applied on the underside by the plasterer. This lath is much used in the construction of flat ceilings, domes, vaults, and other architectural features in interior work, and makes it possible for distinctive effects to be produced, which, on the score of cost, would otherwise be precluded. The development of this application of the material has made it desirable for the manufacturers to employ their own staff of

FIG. 9.—"**Self-Sentering.**"

"Self-Sentering" manufactured by the Self-Sentering Expanded Metal Co., Ltd.

3. Comments on the condition of the existing structure

Overall the structure is in a poor condition with some parts in a very poor condition.

The majority of the structural defects are as a result of water ingress. This has caused corrosion and delamination of elements of the steel frame and rib-lath reinforcement and led to a loss of strength and stiffness. The damage to the structure can be broadly separated into two categories; to the stanchions and roof that form the main elements, and to secondary elements such as steelwork around the windows and the external concrete wall panels.

Most of the areas with the greatest damage are secondary elements such as the angles below the windows. In some places the steel has completely corroded. There is also significant damage to the metal lathing that supports the concrete wall panels as shown in photo 2.

Corrosion has also caused a significant loss of cross-section to a number of the main stanchions. This has resulted in a distortion of the structure as the reduced cross-section can no longer support the weight of the roof structure or lateral loads from wind, see photo 4.

4. Inside of east elevation showing bow in wall

We also noted a longitudinal crack in the underside of the curved roof and a vertical crack in a concrete spandrel panel. This is not continuous and looks to be the result of an outward spread of the top of the walls rather than corrosion of steelwork in the concrete.

5. Cracks at high level

At present there is still sufficient capacity in the steel frames to allow the loads to be redistributed away from the severely damaged sections of steelwork. But if left the damage will continue and eventually lead to a failure and collapse. The structural form means that any failure is likely to be local but it will cause distortions to the surrounding structure and increase the extent of repair/replacement of historic fabric. It will also increase the risk of water ingress and, if not addressed, will accelerate the rate of decay.

We saw that part of the edge of the slab on the west elevation has been exposed by erosion of the ground. The piled foundation means that this is not currently a significant concern.

6. Edge of slab undermined by ground erosion

7. Top of concrete pile exposed by ground erosion

The other main cause of damage, apart from water ingress, is due to invasive vegetation. The growth of plant roots is expanding existing cracks in the finishes and concrete. This damage then allows water to enter the structure. The main area of concern is at roof level where plant growth is exacerbating the damage from cracks in the asphalt finishes, photos 7 and 8.

8. Plant growth at roof level

9. Corroded reinforcement and spalled concrete behind damaged asphalt

4. Recommendations

The key short-term actions to reduce the rate of deterioration are to prevent water ingress and remove plants at roof level. If this is not implemented the damage to the structure will continue until a local collapse occurs. It is not possible to give an exact timescale for when a failure will take place but it could be within the next one to two years.

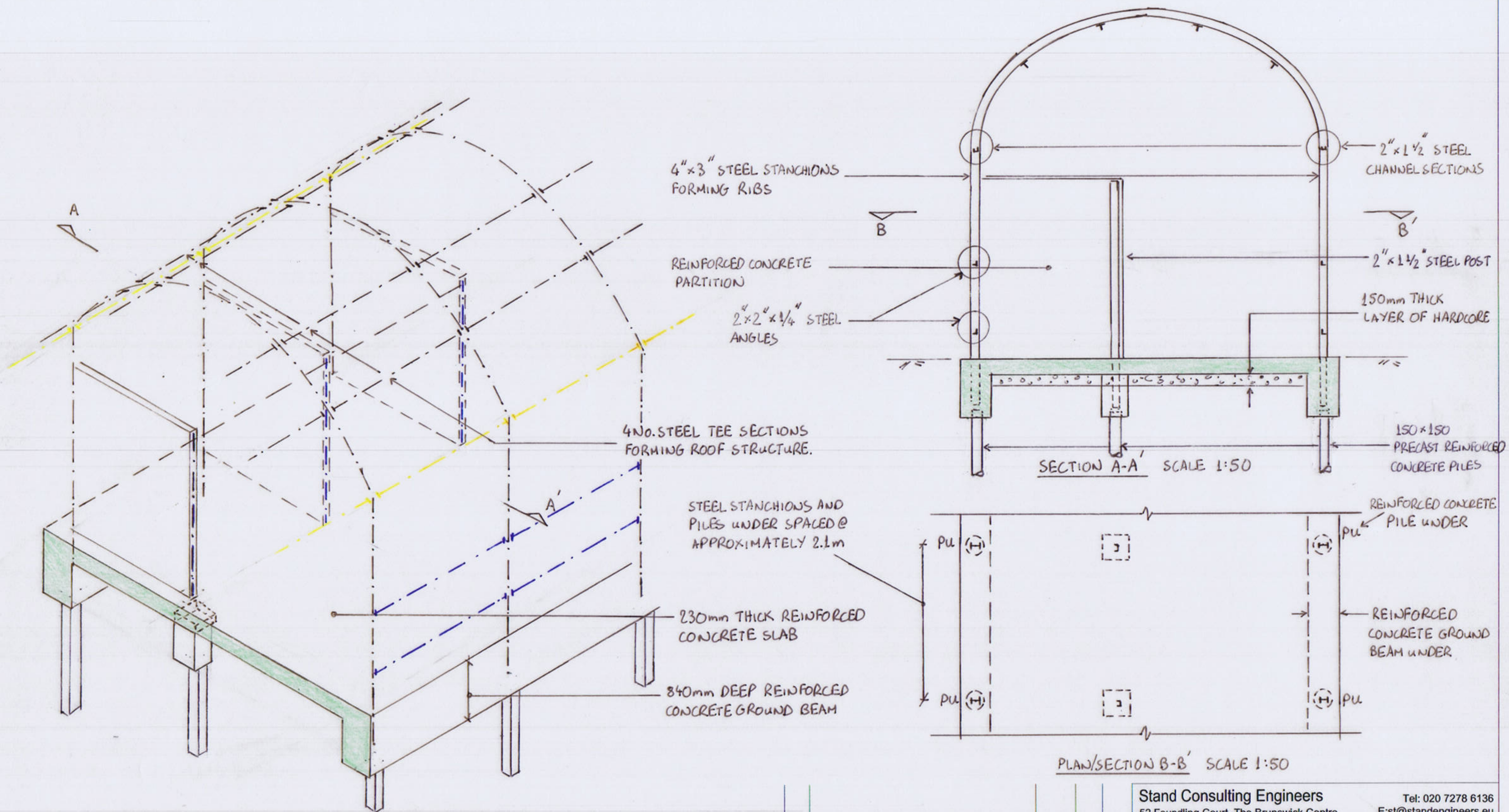
The principles of a conservation-based repair will be linked to the proposed future use of the building. This needs to be discussed as there are a range of options. One approach is to do the minimum necessary to help reduce the rate of damage and decay. A second option could be to repair and restore the building to a particular moment in its life. This would require more significant interventions and the greater loss of historic fabric

Where the steel frame has been exposed by spalled concrete the steelwork should be cleaned and assessed, and then repaired in line with the degree of damage. Superficial damage can be dealt with by applying a corrosion protection and reinstating the concrete. More significant damage will require the addition of new steelwork alongside or welded to the existing metal. The repair of some key steelwork connections is needed where there are signs of structural movement.

As noted above, the external reinforced concrete walls and roof are not part of the primary structure. Their repair is a specialist item and a trial would be needed to assess the process and how to retain the maximum amount of historic fabric. The repair is likely to involve temporary support, the careful removal damaged reinforcement and the addition of a galvanized steel mesh (to follow the principle of the existing construction) and a compatible cement-based render.

Appendix A

Structural Drawing



INDICATIVE 3D SCHEMATIC VIEW OF A STANDARD BAY

SCALE 1:50

SECTION A-A' SCALE 1:50

PLAN/SECTION B-B' SCALE 1:50

REV	DESCRIPTION	DATE	BY	AUTH
P1	ISSUED WITH REPORT	8.11.17	dT	

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PROJECT	TITLE
QUINAN STONE	SUMMARY OF EXISTING STRUCTURE

DATE	DRAWN	AUTHORISED	PROJECT NO.	DRAWING NO.	SCALE @ A3	REV
23.10.17	DV	ST	612	SK1	AS NOTED	P1