MWP

PRELIMINARY STRUCTURAL REPORT

Lower Lighthouse on Skellig Michael

The Office of Public Works

October 2024

Contents

Figures

Appendices

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1. Introduction

MWP were commissioned by the Office of Public Works (OPW) to carry out a structural inspection and report of the Lower Lighthouse on Skellig Michael, Co Kerry.

A structural inspection of the Lower Lighthouse complex on the Skellig was carried out by MWP on 30th of August 2024. The OPW provided 51 archive drawings of the lighthouse on 14th October 2024, together 28 archive photographs. MWP reviewed the archive drawings and extracted the available structural information on the various elements of the building. This information, together with site measurements and observations were used to undertake a structural assessment of the key building elements. This report summarises the findings of the initial visual inspection and assessment and gives recommendations, for further investigation and likely rehabilitation works.

2. Site Location

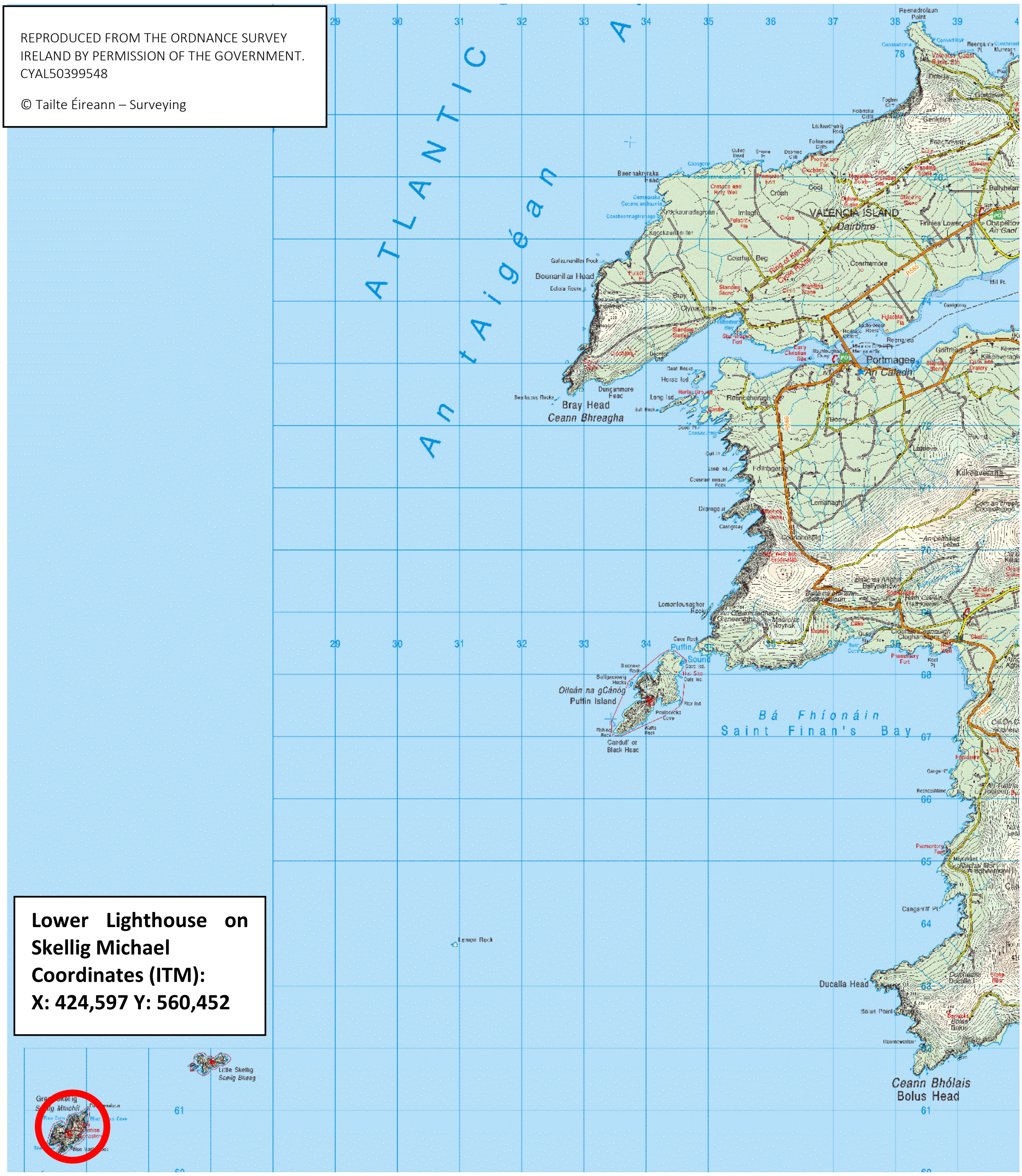

Figure 2-1: Site Location – Lower Lighthouse on Skellig Michael

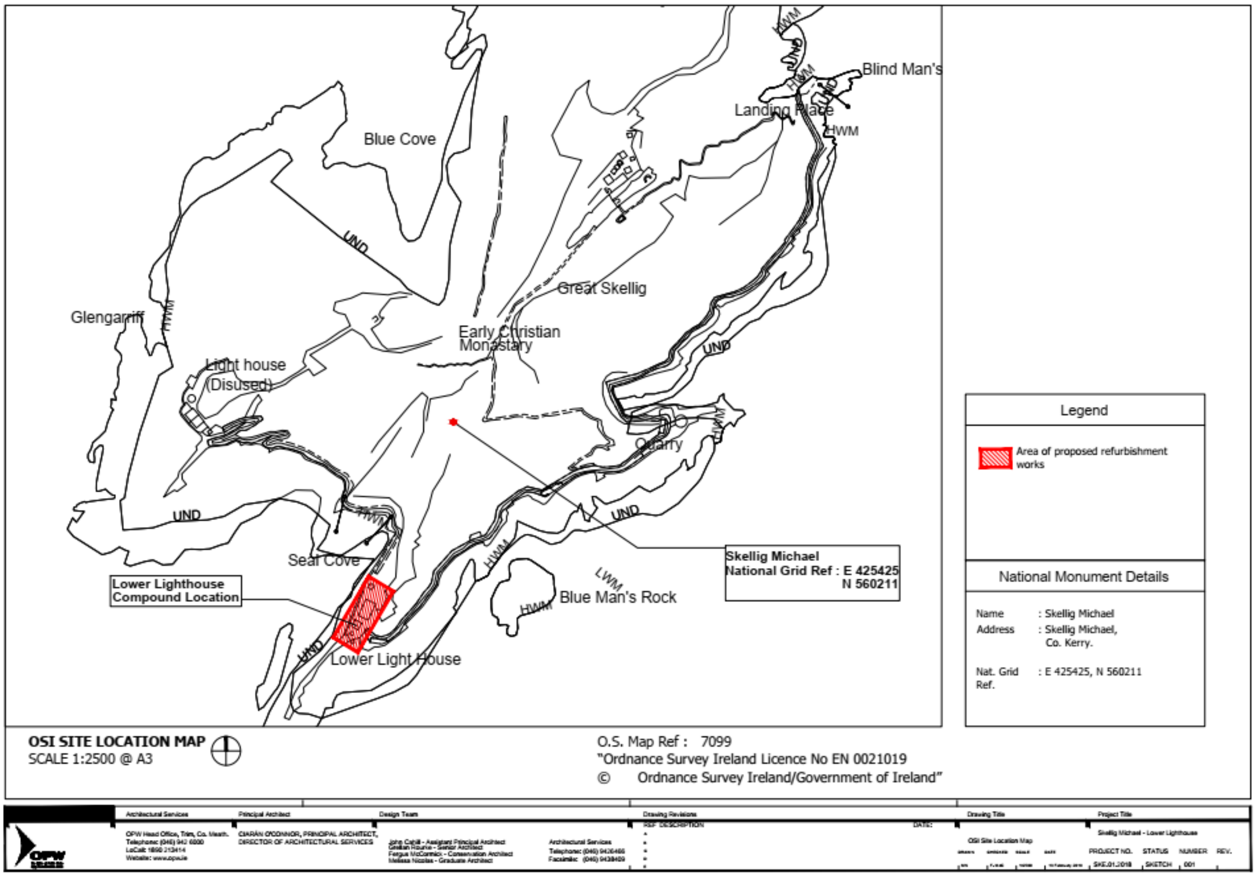

Figure 2-1: Site Location – Lower Lighthouse on Skellig Michael

3. Description of Structure

The Lower Lighthouse complex was completed in 1826 but has seen significant alterations in the intervening years. The keepers' houses originally had a pitched roof but this was removed in 1910 and a reinforced concrete flat roof was added. In 1968, the original lighthouse tower was demolished and a new tower was constructed. The keepers' houses were inhabited until 1987, when the lighthouse was fully automated.

The main elements of the Lower Lighthouse complex are:

- Main two storey block dating from 1826, although the flat roof was added in 1909.
- Single storey annex to north (left in the above photograph) with the same dates as the main block.
- Small entrance lobby to south (right) built in 1968.
- Single storey machine building to the south (right) of the main block. This dates from 1968.
- Lighthouse tower, also dating from 1968.

4. Visual Inspection

An inspection of the Lower Lighthouse was carried out on the 30th August 2024. This was a visual inspection only. While some opening up works had been undertaken in advance of the inspection, no opening up works were carried out during the inspection and no damp or wood rot survey was carried out. There may be latent defects in the building that are not apparent in a visual inspection and MWP can take no responsibility for any such latent defects. The paragraphs below set out the findings of the visual inspection.

4.1 Main two storey block

This building has a concrete ground floor slab, solid masonry walls, timber first floor and a flat concrete roof supported on the steel beams and the masonry walls.

The following was noted from the site inspection and the review of the archive information provided:

- The ground floor slab, while in a reasonable condition, doesn't have any insulation, damp proof membrane or radon barrier.
- The solid masonry walls, i.e. no cavity, are a mix of random stone, cut stone and brickwork. There is no insulation in the walls. Historic photographs show that the external face of the walls were originally clad in slate, but this is no longer present.
- The lintels over the window openings are a mix of cut granite, brickwork, timber and reinforced concrete.
- The first floor consists of timber joists supporting timber floor boards. The joists span front to back and are typically 190mm x 45mm @ 305mm centres. The joists are built into the front and back walls and the central spine wall, on the long axis of the building. Significant wet rot of the timber is present where the joists sit into the walls. This is particularly the case in the front wall.
- Within the front room at the southern end of the block (right hand side when viewed from the front) there was a stairwell which has been removed and floored over. The trimming joists for this seem undersized.
- The ground floor store room to the rear, which currently only has external access, has 200mm x 45mm first floor joists @ 300mm centres. There is a steel beam approximately 1m in from the spine wall and running parallel to it. This was to support a hoist and, while it is underneath the first floor joists, it does not provide support to them.
- The flat roof over the first floor is a 152mm (6") concrete slab with a 25mm (1") layer of asphalt on top. The underside of the slab is plastered.
- The slab is reinforced with an expanded metal. The details of the expanded metal are not available from the archive drawings. However, based on the site inspection, it has little or no cover to the underside of the slab and has suffered from extensive corrosion and loss of section in a number of areas. This corrosion and the resulting expansion of the metal has blown off the concrete cover and plaster in a number of locations.
- The concrete slab is supported by a by four pairs of steel beams spanning between the front, central spine and rear walls of the building. The beams are 254mm x 125mm x 45kg/m (10" x 5" x30lbs/ft) Rolled Steel Joists (RSJ's). The ends of the four joists built into the front wall have suffered severe corrosion and loss of section. Two of these beams have been propped onto the timber first floor, but these are not back propped to the ground floor. While there is some corrosion to the ends of the beams embedded in the spine wall and the rear wall, the beams are still in a reasonable condition.

- Two of the beams at the front and two of the beams at the rear of the building are at over windows. In these four locations, steel spreader beams have been installed to span over the window opening. These spreader beams are very badly corroded.
- There are also steel spreader beams under a pair of the beams in the spine wall. It is assumed that this was to allow for an opening through the wall.
- The beams that are not on spreader beams sit onto granite pads within the wall.
- The ground floor to ceiling height is 2.64m (8' 8") and the first floor to underside of ceiling is 2.97m (9' 9"), although the downstand beams reduce the clear height to 2.72m.

4.2 Single storey annex to the north

This single storey annex has a concrete floor slab, solid masonry walls and a flat concrete roof supported on the masonry walls and two RSJ's.

The following was noted:

- The ground floor slab, while in a reasonable condition, is unlikely to have any insulation, damp proof membrane or radon barrier.
- The solid masonry walls, i.e. no cavity, are a mix of random stone, cut stone and brickwork. There is no insulation in the walls.
- The lintels over the window opening is in cut granite.
- The annex has a flat reinforced concrete roof. The concrete slab is 152mm (6") thick with 19mm (3/4") mild steel reinforcing bars at 152mm (6") centres spanning front to back with two downstand RSJ beams, 204mm x 102mm x 37kg/m (8"x 4" x 18lbs/ft), at third points. The maximum span of the roof slab is 1.52m (5'), while the clear span of the RSJ's is 2.05m (6' 9").
- The flat roof supports water tanks.

4.3 Single storey entrance lobby to the south

This single storey annex has a concrete floor slab, solid masonry walls and a flat concrete roof supported on the masonry walls.

The following was noted:

- The ground floor slab, while in a reasonable condition, is unlikely to have any insulation, damp proof membrane or radon barrier.
- The solid masonry walls, i.e. no cavity, are a mix of random stone, cut stone and brickwork. There is no insulation in the walls.
- The lintels over the windows and doors are reinforced concrete. There is longitudinal cracking evident which indicates that the reinforcing steel in the concrete lintel is corroding.
- The details of the roof are not available, but the span at 2.133m (7') is modest.

4.4 Single storey machine building to the south

This single storey annex was constructed in 1968 and has a concrete floor slab, cavity masonry walls and a flat reinforced concrete ribbed roof supported on reinforced concrete ring beams and the masonry walls.

The following was noted:

- The ground floor slab, while in a reasonable condition. There are some service trenches and it is not known if there is any insulation, damp proof membrane or radon barrier.
- The walls, are cavity construction with a 102mm (4") inner and outer leaf and a 76mm (3") cavity. The external faces are rendered and the internal faces are plastered. There is no cavity insulation.
- The lintels over the windows and doors are in reinforced concrete. The external lintels are 305mm (12") wide by 280mm (11") deep with 4No. 12mm (1/2") reinforcing bars.
- The reinforced concrete ring beams on top of the external walls are the same dimension as the external lintels.
- The reinforced concrete ribbed slab concrete roof spans 5.18m (17') from the front to the back of the building.
- The overall depth of the ribbed slab is 305mm (12"). This consists of 76mm (3") of solid concrete slab with 228mm (9") downstand ribs at 660mm (2'2") centres. The ribs are 127mm (5") wide at the bottom, widening up to 178mm (7") at the underside of the solid slab.
- There is a steel reinforcing mesh in the top of the solid slab and two mild steel reinforcing bars in the bottom of each rib. Unfortunately, the size of the bars or the mesh is not legible on the record drawing (Reel10_032) of the slab. The size of the two bottom bars in the ribs will need to be checked, but it is assumed that they are 25mm (1")diameter.

4.5 Lighthouse tower

The lighthouse tower was also constructed in 1968. While it wasn't part of the building inspection, the walls are 204mm (8") thick reinforced concrete and are in a reasonable condition. The slab supporting the metal and glass lantern structure, on top of the tower, is also in reinforced concrete.

5. Structural Assessment

The following structural elements were assessed, based on information from the site inspection and the archive drawings subsequently provided by the OPW. For each element the structural capacity was checked, assuming no deterioration or loss of section. The impact of any observed deterioration of loss of section is then commented on.

5.1 Main two storey block

5.1.1 First floor timber joists

The 190mm x 45mm joists @ 305mm centres, which are in most of the building, were found to have a live load capacity of 3.0kN/m^2. This is after taking account of the weight of the first floor and allowing for a 1.0kN/m^2 live load for light weight partitions (there are none at present).

The 200mm x 45mm joists @ 300mm centres, above the storage room to the rear, have a live load capacity of 1.7kN/m^2, using the same assumptions. The steel hoist beam, at approximately quarter span of the joists, could be used to increase the capacity of the joists.

The sections of joists that have suffered from wet rot should be cut out and sound timbers spliced on to them. The undersized timber trimmers around the infilled stairwell, at the front of the building, will need to be strengthened.

5.1.2 Concrete roof slab

The analysis shows that an A142 mesh equivalent (6mm diameter bars at 200mm centres) would be adequate to support the slab and a normal flat roof loading (0.75kN/m2). Unfortunately the details of the expanded metal that is reinforcing the concrete roof slab were not on the archive drawings provided. While it is highly likely that the expanded metal did provide the equivalent or greater reinforcing that 6mm bars @ 200mm c.c., and this can be confirmed by opening up a section of the slab, the mesh has suffered extensive corrosion and loss of section in a number of locations. Given this loss of section, the expanded metal can no longer be relied upon to provide adequate reinforcing to the concrete slab.

5.1.3 Steel joists (RSJ's) supporting the flat concrete roof

The steel joists supporting the flat concrete roof slab have a live load capacity of 7.5kN/m^2. This is well in excess of what is required for a flat roof loading. This analysis assumed that the concrete slab provided lateral restraint to the top flanges of the RSJs. This can be checked by further investigation and any deficiencies in restraint can be addressed.

There is significant corrosion and loss of section from the RSJ's, particularly where they are embedded in the front wall of the building. This can be addressed by splicing pairs of steel channels to the ends of the RSJ's.

The steel spreader beams set into the walls, immediately under the ends of the RSJ's in six locations, are badly corroded with full loss of section in some of the beams. These spreader beams should be replaced.

5.2 Single storey annex to the north

5.2.1 Concrete roof slab

This concrete roof slab was designed to take the weight of water tanks and has significant capacity. Both the reinforced concrete slab and the steel joists (RSJ's) supporting it were found to have a live load capacity in excess of 20kN/m^2.

There is some corrosion of the RSJ's but there was no significant loss of section visible during the inspection. The ends of the RSJ's, embedded in the side walls, have the most significant corrosion and may need strengthening.

5.3 Single storey entrance lobby to the south

This single storey annex has a reinforced concrete slab flat roof. Unfortunately, the archive drawings did not give the retails of the slab and therefore the capacity could not be checked. However, the spans are modest and there are no signs of corrosion or spanning on the underside of the slab so it is likely to be adequate to take a roof load. In the absence of any further archive information, a section of the underside of the roof slab should be opened up to establish the size and spacing of the reinforcing steel. The thickness of the slab also needs to be established. There is some longitudinal cracking, spalling and rebar corrosion of one of the downstand beams.

5.4 Single storey machine room building to the south

The roof slab of this building is a reinforced concrete ribbed slab with reinforced concrete ring beams around the edge of the building. This is a very robust type of construction and is in a good condition from a structural point of view.

While the archive drawings give the dimensions of the ribbed reinforced concrete roof slab to this building and also show that there are two mild steel bars in each rib, the size of those bars could not be read from the drawing. In the absence of this key piece of information a back analysis of the slab was carried out to establish the diameter of the two bars in the ribs that would be required to carry a range of live loads on the roof, after allowing for self-weight.

This back analysis showed that for a normal roof live load of 0.75kN/m^2 the two bars need to be 16mm diameter or greater. For a live load of 7.5kN/m^2 (this is equivalent to a typical plant room), the two bars need to be 20mm diameter or greater. While the diameter of the bars in the ribs needs to be established by opening up the bottom of one of the ribs, it is anticipated that the bars are likely to be 25mm diameter.

6. Summary and Recommendations

A structural inspection of the Lower Lighthouse complex on the Skellig was carried out by MWP on 30th of August 2024. The OPW provided 51 archive drawings of the lighthouse on 14th October 2024, together 28 archive photographs. MWP reviewed the archive drawings and extracted the available structural information on the various elements of the building. This information, together with site measurements and observations, were used to undertake a structural assessment of the key building elements. Set out below is a summary of the findings and recommendations of the structural inspection and assessment.

6.1 Main two storey block

6.1.1 First floor timber joists

It should be possible to retain these joists which have adequate load carrying capacity to take a domestic or light office loading. However, the extensive wet rot needs to be addressed by cutting off the affected lengths of joists and splicing on new sections of treated timbers. The undersized timber trimmers around the infilled stairwell at the front of the building will need to be strengthened.

6.1.2 Concrete roof slab

Unfortunately the details of the expanded metal, that is reinforcing the concrete roof slab, were not on the archive drawings provided. While it is highly likely that the expanded metal did provide adequate reinforcing to the slab, and this can be confirmed by opening up a section of the slab, the mesh has suffered extensive corrosion and loss of section in a number of locations. Given this loss of section, the expanded metal can no longer be relied upon to provide adequate reinforcing to the concrete slab. The slab therefore has to be either replaced or repaired and strengthened. Given the difficulties that would arise from removing and replacing the roof slab, it is recommended that the repair and strengthen option be pursued.

The repair and strengthening option will require detailed consideration and design, but is likely to consist of the following:

- Remove all the plaster from the underside of the slab.
- Remove any loose or hollow concrete cover to the expanded metal.
- Mechanically clean the exposed expanded metal to remove and rust product.
- Apply a rust inhibitor to the exposed expanded metal.
- Fix additional mesh to the underside of the slab. A grid of shear bars (dowels) will likely need to be drilled and grouted into the slab to provide a shear key between the original slab and the additional mesh.
- Gunite (a sprayed structural render) the underside of the slab to encapsulate the additional mesh and the exposed expanded metal.

In advance of progressing with this design, any additional loading proposed for the roof slab will need to be established. Localised loads, such as water tanks, can be catered for by additional structural steel work but more widespread loads, such as mechanical plant or solar panels, will need to be carried by the slab.

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6.1.3 Steel joists (RSJ's) supporting the flat roof

The RSJ's supporting the roof slab have adequate load carrying capacity. However, the significant corrosion and loss of section, particularly where the RSJ's are embedded in the front wall of the building, needs to be addressed by splicing pairs of steel channels to the ends of the RSJ's.

The steel spreader beams, set into the walls immediately under the ends of the RSJ's, should be replaced.

All structural steelwork being retained should be mechanically cleaned and then painted. Some steelwork may also need to be protected from fire, but that is outside the scope of this report.

6.2 Single storey annex to the north

Both the reinforced concrete roof slab and the steel joists (RSJ's) supporting it were found to have a live load capacity in excess of 20kN/m2. There is some corrosion of the RSJ's but there was no significant loss of section visible during the inspection. The ends of the RSJ's, embedded in the side walls, need to be further investigated for corrosion and repaired if necessary.

6.3 Single storey entrance lobby to the south

This single storey annex has a reinforced concrete flat roof slab. While structural information was not available from the archive drawings, the slab is in a reasonable condition and is likely to have adequate capacity to take a roof load. A section of the underside of the roof slab should be opened up to establish the size and spacing of the reinforcing steel. The thickness of the slab also needs to be established. The cracked concrete downstand beam needs to be repaired.

6.4 Single storey machine room building to the south

The roof slab of this building is a reinforced concrete ribbed slab with reinforced concrete ring beams around the edge of the building. This is a very robust type of construction and is in a good condition from a structural point of view.

Unfortunately, the size of the reinforcing bars in the ribs is not known at present. However, the back analysis showed that for a normal roof live load of 0.75kN/m2 the two bars in the ribs need to be 16mm diameter or greater. For a live load of 7.5kN/m2 (this is equivalent to a typical plant room), the two bars need to be 20mm diameter or greater. It is highly likely that the roof of this building will have the structural capacity to carry a plant room. The bottom of one of the ribs should be opened up to check the bar size and allow the capacity of the roof to be established.

6.5 Other elements

The lack of a damp proof membrane in the ground floor slabs will need to be addressed. It will also need to be established whether a radon barrier is required.

Damp penetration through the walls of the main building and the northern annex needs to be addressed.

There are a number of reinforced concrete lintels that have cracking which is likely be as a result of corrosion and expansion of the reinforcing steel in the lintel. These will need to be opened up to establish the extent of corrosion so a assessment can be made as to whether the lintel can be repaired or has to be replaced.

There are some timber and brick lintels that need to be exposed so that they can be assessed.

The adequacy of the asphalt covering to the flat roofs needs to be checked.

Appendix 1

Photographs

Photo 1: Archive view of original Lower Lighthouse buildings

Photo 2: Archive photograph of original two storey building with pitched roof and slate cladding on external walls

Photo 3: Current view of Lower Lighthouse

Photo 4: View of front (western) facade

Photo 5: Cracking and exposed rebar in downstand beam of room off entrance

Photo 6: Cracking and corrosion of rebar in ground floor window lintel

Photo 7: Sagging timber lintel over ground floor window

Photo 8: Cracking of bricks in ground floor window lintel

Photo 9: Trial hole in ground floor slab

Photo 10: First floor timber joists built into front wall

Photo 11: View of underside of first floor timber joists

Photo 12: View of underside of first floor timber joists

Photo 13: First floor timber joists trimmed around old stairwell opening

Photo 14: View of RSJ's supporting concrete roof slab of northern annex

Photo 15: View of expanded metal in first floor roof slab

Photo 16: Close up view of corrosion of expanded metal in first floor roof slab

Photo 17: RSJ supporting roof slab bearing onto steel spreader in rear wall

Photo 18: RSJ supporting roof slab bearing onto corroded steel spreader in front wall

Photo 19: Propped roof RSJ bearing onto front wall

Photo 20: Propped roof RSJ bearing onto front wall

Photo 21: Corrosion of end of roof RSJ built into front wall

Photo 22: Roof RSJ bearing onto granite pad in rear wall

Photo 23: Roof RSJ's bearing onto steel spreader in spine wall

Photo 24: Underside of concrete rib slab roof of single storey machine room

Photo 25: Roof of single storey machine room and entrance annex

Photo 26: Flat roof of main two storey block