RAAC Panel Management
West Suffolk Hospital

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RAAC Panel Management
Structural Engineering Investigation Report

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1 Introduction

MLM have been advising the Trust on the structural condition of the concrete element of the structural and the RAAC elements specifically for some considerable time. Investigations commenced in 2009 and since that time various detailed investigations have been undertaken and reports prepared to advise the Trust on the state of the building structure. Recently, the issues associated with RAAC have been subject to much discussion and debate across the NHS and the report has been prepared to summarise the investigation and reports undertaken by MLM. The advice provided by MLM has been to identify and assess the structural risks presented by the RAAC to allow the Trust to develop management plans and risk assessments to assess the safety of the ongoing continued use and safety of the hospital.

2 Background

MLM have directed several investigations and assessments of the RAAC panels at West Suffolk Hospital. These have included investigations into the RAAC roof panels and load bearing RAAC wall panels. The non-loadbearing RAAC internal wall panels have not been subject to inspection or assessment in detail.

The investigations have been presented in the following reports:

Reference no.	Title	Reference	Date
1	Condition Survey of the building exposed external concrete: Part 1 Pre-cast Autoclaved concrete panels	MCL/661656/DAW	August 2009
2	Condition Survey of the building exposed external concrete: Part 2 reinforced concrete elements	MCL/661656/DAW	August 2009
3	Structural Survey and Roof Panels	MCL/661656	February 2010
4	Structural Assessment of Wall Panels	MCL/661656/JMM	April 2010
5	Management of AARC Roof Panels	666814-MLM-ZZ-XX-RP-S-0002	March 2018
6	Quinquennial Inspection of Roof Panels	666814/MLM-ZZ-X-RP-S-0005	October 2018
7	Wall Panel Structural Assessment	666814/MLM-ZZ-X-RP-S-0006	April 2019
8	GBG Investigation of RAAC Roof Panels	4634A	January 2020
9	GBG Autoclaved Concrete RAAC Roof Planks wards G4 & G5	4634B	November 2020
10	RAAC Panels monitoring – Structural Commentary to Castons Interim Report	660778-MLM-ZZ-XX-RP-S-0001	December 2020

3 Summary of Previous Reports

3.1 Condition Survey of the buildings exposed external concrete Part 1: Pre-cast Autoclaved Aerated Panels dated August 2009.

This report was the first step on the investigation and assessment of the RAAC at the hospital. The investigation included visual surveys, non-destructive testing and some intrusive trial holes into the wall construction. The report made recommendations for the implementation of a management regime and for further assessment.

3.2 Condition Survey of the building exposed external elements. Part 2: Reinforced Concrete.

In parallel with the assessment of the RAAC panels, the normal weight concrete elements were inspected and surveyed both non-destructively and intrusively. The edge beams were found to be in good condition but some corrosion within the external stairs was detected (possibly due to the use of de-icing salts).

3.3 Structural survey of the roof panels dated February 2010.

In response to the recommendations of the report in 3.1 above, a further inspection and assessment of the roof panels was undertaken. The assessment included measurement of panel deflections, trial holes to look at the plank bearings and visual inspections. The report included recommendations for ongoing inspections, the instigation of investigations of any reported damage as well as consideration of recovering of the roof with improved drainage and thermal performance.

3.4 Structural Assessment of wall panels dated April 2010

An inspection and assessment of the wall panels to the main hospitals and residencies blocks was undertaken. The works included intrusive and non-intrusive testing including the collection of cores for laboratory strength testing. Structural calculations were prepared using a range of design guides contemporary to the hospital construction and modern guides. The report concluded that as built, the panels have adequate strength and fire resistance but that corrosion could structurally weaken the panels. The consideration of measure to minimise corrosion as well as the implementation of structural repairs to damage was recommended.

3.5 Management of AARC roof panels dated March 2018

The report set out proposals for the ongoing management of the roof panels. It included a summary of action levels for panels based on their deflection and structural deterioration. It sets out recommendations for the management of inspections and also Extreme Weather Procedures.

3.6 Quinquennial Inspection of Roof Panels dated October 2018

The management procedure included recommendations for a Structural Engineering Assessment on a Quinquennial basis. The investigation included deflections measurements including the re-surveying of panels measured in the 2009 survey. The report recommended the detailed inspection of concealed panels and trials of “tap testing” to access the extent of loose or de-bonded concrete.

3.7 Wall Panel Structural Assessment dated April 2019

A detailed programme of intrusive investigations and testing was undertaken with assistance from the Building Research Established (BRE). (The works followed on from a similar investigation into the roof panels at the Queen Elizabeth Hospital). The conclusions identified that the condition of the panels was variable across the hospital with some structurally weakening corrosion. It discussed various options for the wall panels and if a “Do Nothing” approach was adopted the panels would become unsafe in say a 10-20-year period. Recommendations included on going monitoring, developing a strategy for the management of the wall panels as well as a future monitoring regime.

3.8 GBG Investigations of RAAC Panels dated January 2020

GBG are a specialist investigation company and their services include a range of non-destructive testing using radar survey techniques. Twenty-three roof panels were investigated in four locations around the hospital. The aim was to assess whether radar surveys were an effective method of identifying the position of transverse bars at the plank bearings. The trial could generally position the bars to an accuracy of ±15mm and the trial was therefore considered to be successful. The panels surveyed were found to have the transverse bars within the bearing length (with one exception which needs intrusive works to verify the position).

3.9 GBG Autoclaved Concrete (RAAC) Roof Panels Ward G4 & G5 dated November 2020

A large-scale area of radar testing was undertaken and 600 plank ends were investigated. The survey built on the earlier trial and the technique was further advanced to be able to identify the beam bearing position. In all planks surveyed the transverse bars were found to be correctly positioned over the bearing.

3.10 Structural Commentary to Castons Interim Report dated December 2020

A fully detailed "hands on" survey was commenced by Estates staff and is now being progressed at the hospital under a contract with Castons – a building surveying company. The report sets out some background information. The report concludes that the monitoring results are a useful part of the management of the panels although monitoring alone may not be able to predict all failure modes. Therefore, the planned installation of failsafe/supports to the roof panels should continue.

4 Current Investigations

4.1 The previous investigations have highlighted that corrosion of the reinforcement within the wall panels could structurally weaken the panels. If corrosion became extensive the possibility of a local collapse cannot be excluded. In October 2020 work commenced on a programme of testing and research to undertake trials of non-destructive testing methods that are used on normal weight concretes to see if they could be effective on RAAC. A specialist corrosion engineering consultancy - Concrete Preservation Technologies – (CPT) have been instructed to undertake a series of laboratory and insitu measurements. They will also assess whether corrosion detection and prevention methods used on normal weight concrete would be effective on RAAC. Tests have been ongoing using a range of techniques which including:

- Insitu carbonation depth testing
- Chloride testing
- Resistivity measurement
- Close Internal Potential Map surveys
- Direct-Current Voltage-Gradient mapping.

At the time of writing this report this work is ongoing. The tests have had some success and a larger scale trial is just commencing.

4.2 Work is also underway on further radar surveys by GBG to include some planks between the north light and the roof area over the Estates Block. When this work is completed, approximately 27% of the roof planks will have been subject to radar surveys.

4.3 The surveys being undertaken by the trust personnel and specialist contractor (Castons) is ongoing. The surveys include the completion of the roof panel inspections and a comprehensive survey of the external wall panels. The surveys are categorising all damages being recorded so that each panel has a unique identification reference.

5 Discussion

The structural engineering issues associated with the RAAC roof and wall panels have been discussed in the reports summarised above and most recently in our report in December 2020 – Structural Commentary to Castons Interim Report.

5.1 West Suffolk Hospital was constructed in the early 1970's and was built as one of the "Best Buy" hospitals. The building was constructed utilising precast concrete construction. The central "spine" of the building and first floor are of traditional normal weight precast concrete construction. The external wall panels and roof panels are formed from precast Reinforced Autoclaved Aerated Concrete (RAAC) panels.

RAAC panels were an innovative form of construction at the time most likely used to provide enhanced thermal performance over normal weight concrete.

Across the country defects started becoming apparent within RAAC panels soon after this introduction and in the 1990's some research was undertaken by the Building Research Establishment (BRE) into panels designed and installed before 1980.

Due to the nature of the RAAC material at West Suffolk Hospital, defects became apparent and concerns began to be raised in 2009 about the condition of the structure at the hospital. Since that time, extensive investigations have been undertaken by MLM and with some assistance from BRE and these have identified that the RAAC has numerous structural deficiencies and defects.

In May 2019, a SCOSS Alert was issued by the Institution of Structural Engineers which discussed the findings of an investigation into the catastrophic failure of a roof panel in a school. Since then, further reports issued by SCOSS has identified that a roof plank has failed at another school in 2017.

5.2 RAAC can be distinguished from normal weight concrete by:

- A much lower strength ranging from about 2 – 5 N/mm² compared to 30 – 50 N/mm² for standard concrete.
- The AAC material is permeable and the embedded reinforcement relies on a coating applied to the bars to provide protection against corrosion.
- The main reinforcement in the planks rely on the action of welded transverse bars to anchor the bars at the end bearing of the planks.

RAAC roof panels have experienced structural problems since soon after their introduction as a building material. Issues have included:

- Deflection of roof panels resulting in the ponding of water.
- Transverse cracking resulting from the large deflections.
- Corrosion of embedded reinforcement due to breakdown of the protection coating and exacerbated by water leaks and/or interstitial condensation.
- Short end bearing lengths which in conjunction with poor workmanship could result in inadequate bearing conditions.
- Concern about the structural integrity of the planks due to reinforcement corrosion.
- Spalling concrete resulting from corrosion and/or mechanical damage.

The roof panels at West Suffolk Hospital have been extensively investigated by MLM since 2009 and defects associated with these issues have been identified at the hospital.

5.3 In addition, the external wall panels are constructed from RAAC panels. Unusually, these panels are load bearing and support the first floor and roof construction. These wall panels were subject to an extensive investigation during 2018-19 including input from the Building Research Establishment. The report identified widespread defects including:

- Cracking of the AAC material.
- Surface corrosion of the embedded reinforcement.
- Spalling of concrete in isolated locations due to corrosion of embedded reinforcement.
- Localised honeycombing of the AAC material around the reinforcement.

The report concluded that the prediction of the future life of the building is difficult due to the lack of information about RAAC panels. However, if a "Do Nothing" approach is followed, the panels could possibly become weakened and unsafe in a 10 year period i.e. by 2030.

5.4 In response to the concern from the SCOSS report and the wall panel investigation, a review of the roof construction was undertaken in May 2019 and this concluded:

- The condition of the roof panels were investigated in 2010 and have been subject to ongoing consideration since that time.
- The roof has been recovered over much of the hospital since 2010 and insulation laid to falls has been added. These actions help to remove excess weight off the roof from ponding water and keeps the panels dry but other deficiencies remain.
- At the time of the commencement of the re-roofing it was estimated that the works may extend the life of the structure for a about a 20 year life (i.e. to about 2030).
- Extensive management regimes have been put in place by the Trust including an Extreme Weather Procedure, 5 yearly (quinquennial) reviews and day to day management procedures. Since 2019, annual standard engineering inspections have been undertaken.
- During the day to day management of the buildings, defects are regularly reported and after investigation some have led to the introduction of structural strengthening measures of individual planks and some wider spread areas.
- Further investigations at the hospital have identified extensive significant concerns about the structural integrity of the roof panels. The serviceable life is now considered to be no more than 10 years (i.e. up to 2030) and failsafe supports are needed in the interim period.

Due to the nature of the original construction and the extensive deterioration of the panels, it is apparent that an unpredicted failure of a roof or wall panel could occur with little or no warning.

5.5 The extensive investigations and assessments over the last 11 years has allowed a detailed understanding of the structural condition of the roof and wall RAAC panels at the hospital to be gained. From this it is understood that the long-term performance of the structure cannot be guaranteed and that it must be considered that the structure will become unsafe within the next 10 years.

In the context where an unpredicted failure of a panel could occur, monitoring processes have been established in order to minimise the residual risk. The intended processes include:

- Providing a triage system for panels to assist with prioritising panels for implementation of reactive measures (including installation of temporary propping and failsafe supports)
- Establishing a baseline record of the condition of each panel specifically and the panels generally to assist future judgements of condition and rates of deterioration

While the monitoring is considered an essential contribution to best-practice management of the structure, it should be understood that the survey is limited to those features which are observable by visible and tactile inspection and it cannot be assumed that all defects detectable visually.

5.6 The RAAC panel collapses reported by SCOSS have been attributed to failure near bearings in a shear failure mode. Scientific research into this failure mode has been recommended but has yet to be implemented and the causes and warning signs of this failure mode remain poorly understood.

Defects contributing to shear failure may include concealed features including manufacturing defects (such as misplaced reinforcement), construction workmanship defects (such as concealed damage and short bearings) and corrosion or other ageing effects (which might not lead immediately to a visible feature on the accessible surface). Therefore, while visible features of deterioration remain an important consideration in assessing the condition of a panel, there may be other factors which remain unknown which alter the risk profile of an individual panel.

5.7 Deterioration of the panels by reinforcement corrosion has a correlation with detectable features on the surface of panels (including cracking, deformation and hollow features. However,

- Surface features do not occur until after the onset of corrosion
- Some panels are known to have been repaired in the course of the building's history but the locations and extents of repairs are not all recorded and may not be apparent

Therefore, the frequency of instances of corrosion-related features recorded by the monitoring survey would not be expected to represent the full extent of corrosion activity.

A phased programme of re-roofing has been ongoing for several years to address roof leaks with the intention of reducing causes of corrosion in the roof panels. It is also intended that the introduction of failsafe measures will mitigate the impact that ongoing corrosion will have on the operational activity of the hospital by addressing risks associated with spalling of material from roof panel soffits.

Once initiated, corrosion is progressive and is expected to worsen over time. The rate at which corrosion will lead to observable defects remains uncertain. Therefore, ongoing management and monitoring is recommended for the roof and wall panels.

5.8 A separate programme of trials is underway to investigate the effectiveness of techniques for non-destructive detection of active corrosion and possible protective measures to slow rates of corrosion in the wall panels. Such techniques, while well established for normal dense reinforced concrete, are not well established for RAAC (which has some similarities but significant differences). Until these trials are complete, a cautious approach to interventions is prudent due to the possibilities that these may have unintended consequences of either exacerbating corrosion or reducing the potential effectiveness of future interventions.

5.9 Previous investigations of the wall panels have identified that surface features such as staining, crazing, and more minor cracking, may be limited to surface finishes and may not be associated with defects in the RAAC panels. However this cannot be positively confirmed without intrusive works. Nevertheless, it is important that these features are recorded in the monitoring survey as a point of comparison for future inspections. Recently, roof panels under heavily used roof access walkways have been found to have damage. The areas under walkways are therefore a higher risk than un-trafficked areas.

5.10 A survey exercise using radar techniques has been conducted by GBG Structural Services for part of the roof area, to locate anchorage reinforcement at RAAC panel bearings. If anchorage reinforcement in a RAAC panel were to be absent or incorrectly positioned, the risk of a sudden shear failure would be higher. GBG Report ref. 4634B dated 30 November 2020 has been produced following survey of part of the roof (over Wards G4 and G5). The report identifies that in the areas of roof surveyed, the panels surveyed all had anchorage bars within the bearing area of the supporting beams.

5.11 The SCOSS Alert gave recommendations regarding the management and assessment of the RAAC planks. These are summarised below with commentary.

SCOSS Recommendations	Commentary
Conduct a Risk Assessment.	Risk Assessment done by the Trust and ALARP review undertaken.
Consider a long-term plan.	Proposals for failsafe supports underway and plans to replace the building by 2030.
Colour of roof surfacing.	The re-roofing has included insulation which will protect the planks for thermal gain.
Ensure staff are informed.	All staff including clinical staff have been briefed.
Audible cracking sounds.	A repointing structure is in place.
Observations and warnings.	The Management Plan includes for referral to a Structural Engineer if appropriate.
Examine the structure.	Detailed surveys include radar testing which is done and progressing.
Measure deflections.	Done as part of surveys.
Note cracking.	Done as part of surveys.
Pay attention to shear cracks.	Done as part of surveys.
Check for water ingress.	Done as part of surveys.
Check for position of transverse reinforcement.	Done as part of radar surveys.
Check tension reinforcement extent to plank ends.	Done as part of radar surveys.
Consider collapse mechanisms.	Included in Risk Assessment.
Confirm plank composition.	Done within the extensive reports since 2009.

5.12 The Internal Structural Team has directed considerable resource towards the RAAC issues in terms of both personnel time, leadership from the Executive team and the use of external contractors to provide assistance with the surveys and with the installation of temporary props and reactive failsafe supports. These works have extended over some years now and the Team have developed a considerable understanding of the issues with the RAAC panels. The expertise has been used to develop a comprehensive management plan and risk assessment process which has been seen and supported by the Executive team.

6 Conclusions

6.1 It has been known since the 1980's that RAAC roof panels designed and installed in the 1960's and 1970's show sign of deflection. Research undertaken in the 1980's by the BRE gives guidance based on the deflection with trigger levels for increasing urgency of actions.

6.2 The early investigations at West Suffolk Hospital in 2009 and 2010 identified that deflections have occurred to the roof panels and although the measured deflections were generally below the highest trigger level, there were issues that needed further investigation and consideration.

6.3 Some transverse cracking within RAAC panels installed in the 1970's can be expected due to the higher than anticipated deflection of the panels. However, the variable patterns of cracking together with the other defects associated with the ageing of the panels means that there is some doubt about their structural adequacy.

6.4 The short bearing length of the planks gives rise to a need for the precise fixing of the transverse reinforcement within the planks and the correct positioning of the planks during installation. Any poor workmanship during the construction could raise concerns about the risks of shear failure at the bearings.

6.5 Although no significant or sudden change have been observed in the panels the general picture is one of progressive deterioration. The level of knowledge available about when RAAC panels become unsafe is low compared to other structural materials and therefore a degree of caution is needed to reflect the level of uncertainty. The detailed condition survey of the panels will help to access the rate of deterioration over the coming years.

6.6 The possibility of uncontrolled or ill-informed structural alterations to the planks either during installation or during building modification raises concerns about the integrity of altered panels. Instances of planks damaged by maintenance work on the hospital since construction have been observed.

6.7 The risk of standing water on the roof and damage from roof leaks have been considered and a programme of re-covering of the roof has been undergoing for several years and is now nearly complete.

6.8 A robust management plan is required whereby the condition of the panels can be assessed and proactive measures put in place to any panels or areas of concern. (The survey work was commissioned some time ago by the estate team and is progressing via the use of a contractor. A Management Plan has been put in place by the Estates Team and it is understood to be subject to regular review by the team and the Executive Leadership).

6.9 When damaged panels are observed they should be assessed by the Estates team for the installation of propping and/or failsafe supports and if there is any doubt MLM is to be consulted. The management surveys have identified some 200+ panels where actionable damage has been seen and these have been addressed by the installation of failsafe supports.

6.10 The condition of the wall panels is of some concern and a detailed condition survey is required and is now largely complete. Where panels are seen to have significant areas of corrosion or damage they should be identified for a Structural Assessment and repair if required.

6.11 The process should be subject to ongoing risk assessment and review. The assessment to be based against the recommendations of the detailed ALARP review undertaken in 2020.

6.12 The RAAC panels have been subject to detailed and considered management by the Estates team for several years. The work has included detailed surveys and assessment of planks for temporary propping and failsafe supports. During this time the team and the leadership have gained considerable knowledge and expertise.

6.13 All recommendations of the SCOSS Alert have been addressed by the historical reports and the current Management Plans and Surveys undertaken by the Trust.

6.14 The extensive surveys and inspection have shown that the roof and wall panels have widespread cracking and that there are concerns about the structural condition of the panels. During the works there have been concerns identified about the panels but there have been no instances of a whole panel failure at the hospital. Therefore, a proactive approach to the management of the situation is prudent, with the installation of the failsafes to the roof panels to be implemented as a priority. The current programme to commence installation later this year should be maintained.

6.15 With a management plan in place the risks can be kept under review. However, based on the extensive investigation and surveying, it is now considered that a serviceable life span of the building beyond a 5 to 10 year period is unlikely and that it should be planned to replace the building by 2030.

6.16 The observed deterioration raises concerns about the possibility of structurally weakening damage and therefore the occurrence of an unexpected partial or total failure of a roof or wall panel cannot be excluded. The installation of failsafe supports to the roof panels across the whole of the building and structural assessment of the observed damage to the wall panels is a priority action – both of which are underway.

7 Recommendations

Our current recommendations are summarised below:

7.1 The hands-on survey of the roof and wall panels commenced by the Estates team and now being progressed by contractor should continue. The survey to include the difficult to access areas.

7.2 The radar surveys underway by GBG to be completed and the findings assessed.

7.3 The findings of the survey shall be subject to constant review and any damaged panels assessed. The assessment to identify whether the panels should be subject to continued monitoring or whether propping is required and/ or the implementations of localised failsafe supports.

7.4 The deterioration of the wall panels to be assessed by the ongoing works with CPT and the impact on the risk of structurally weakening damage reviewed.

7.5 Wall panels rated as “actionable” by the survey should be assessed and instructed, repair undertaken as required.

7.6 The programme to undertake intrusive failsafe supports across the whole of the Estate should continue with failsafe installation commencing as soon as practicable. The works to progress to the agreed programme with the works targeted to compete in Autumn 2022

7.7 The planning to replace the hospital by 2030 at the latest should continue.

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