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Standing Committee on Structural Safety

SCOSS Alert | May 2019

FAILURE OF REINFORCED AUTOCLAVED AERATED CONCRETE (RAAC) PLANKS

In late 2018, the Local Government Association (LGA) and the Department for Education (DfE) contacted all school building owners› to draw attention to a recent failure involving a flat roof constructed using Reinforced Autoclaved Aerated Concrete (RAAC) planks. There was little warning of the sudden collapse.

Although the failure was in a school, it is believed that RAAC planks are present in many types of buildings. This Alert is to emphasise the potential risks from such construction, most of which dates back to between the 1960-80s. Although called "concrete", it is very different from traditional concrete and, because of the way in which it was made, much weaker. The useful life of such planks has been estimated to be around 30 years.

Pre-1980 RAAC planks are now past their expected service life and it is recommended that consideration is given to their replacement.

1. Who should read this Alert?

Owners of schools and similar buildings dating from the 1960-80s with flat roofs. Government Departments and Local Authorities who have schools and similar buildings in their asset portfolios. National Health Trusts, Dioceses/Parishes, building surveyors, architects, structural engineers, facilities managers and maintenance organisations may also be interested.

2. Background

In the 1980s there were many instances of failure of RAAC roof planks installed during the mid-1960s and a large proportion of such installations were subsequently demolished [1]. Several case studies revealed some primary deficiencies e.g. incorrect cover to the tension steel, high span-to-depth ratio, insufficient provision of crossbars for providing anchorage for the longitudinal steel, failure in performance of roof membrane and rapid worsening of local corrosion of steel.

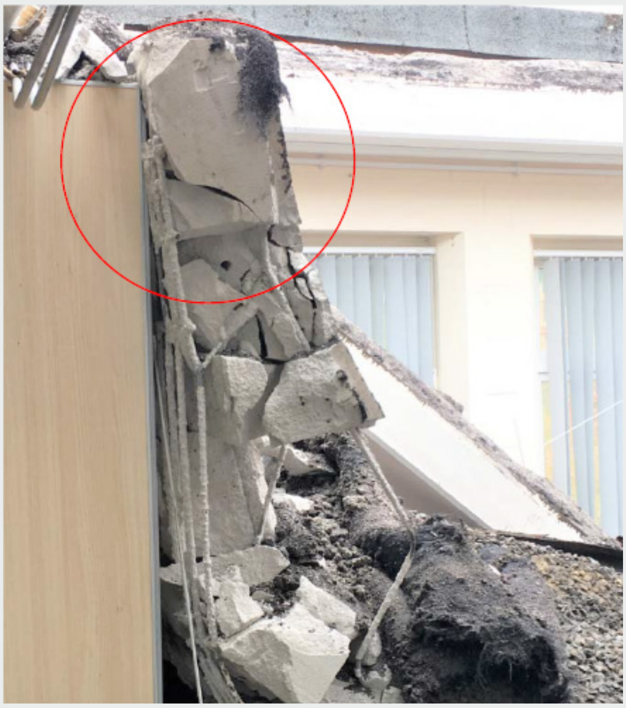

Figure 1
The 2018 roof slab collapse

It is known that RAAC was used for walls and it is possible that there were RAAC floor planks, but no failures of these have been identified in the present review.

BRE published an Information Paper in 1996 [1] which stated that excessive deflections and cracking had been identified in a number of RAAC roof planks and evidence of initiation of reinforcement corrosion was found. This was followed in 2002 [2] with further information on performance issues, laboratory testing, and advice on inspection.

More recent investigations of externally exposed load bearing wall panels have found that corrosion was initiated even where the bituminous coating appears to have been visibly intact. Severe corrosion of the reinforcement embedded in RAAC wall panels bordering shower rooms and toilets has also been recently identified.

Concerns that had arisen with roof planks include:

- Rusting of embedded reinforcement leading to cracking and spalling of the AAC cover;
- Cracking, of varying degrees of severity, thought to be associated with moisture and temperature related movements in the planks;
- Excessive deflections due to creep;
- Floor and roof planks tending to act independently, rather than as a single structural entity.

In some cases, the deflections had become appreciable, with span-to-deflection ratios in the order of 100. This could lead to:

- ponding of rainwater, with the potential increase in the imposed loading,
- distress to certain types of waterproof membrane and associated finishes, and
- water penetration sufficient to promote corrosion of the embedded reinforcement.

SCOSS (Standing Committee on Structural Safety) also warned of the problem in the **Twelfth Report of SCOSS** in 1999 [3] (see Section 3.5 Reinforced autoclaved aerated concrete). Since then, there will have been deterioration, possibly effects from maintenance or refurbishment, or a change in environment, all of which can adversely affect long-term performance.

INFORMATION

What is RAAC?

Autoclaved aerated concrete (AAC) is different from normal dense concrete. It has no coarse aggregate, and is made in factories using fine aggregate, chemicals to create gas bubbles, and heat to cure the compound. It is relatively weak with a low capacity for developing bond with embedded reinforcement. It was used in two main forms of structural elements; lightweight masonry blocks and structural units (such as roof planks, wall and floor units).

When reinforced (Reinforced AAC: RAAC) to form structural units, the protection of the reinforcement against corrosion is provided by a bituminous or a cement latex coating, which is applied to the reinforcement prior to casting the planks. The reinforcement mesh is then introduced into the formwork and the liquid AAC mix added.

Figure 2
A lump sample of AAC [1]

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3. Recent RAAC failures

In the case of the 2018 failure, there was evidence of shear cracking adjacent to a support and possible indications of tension reinforcement stopping short of the support. It was noted during investigation that the roof had been recently resurfaced. Also, the failure was at a time of hot weather, so there may have been a thermal influence.

In early 2019, SCOSS were informed of damage to RAAC roof planks at a retail premises. While the planks did not collapse, there were localised issues, including spalling of concrete, on a small number of planks that otherwise appeared in sound condition. In this case, the cause of the damage is thought to be water ingress, including at the location where a rainwater outlet had been previously installed and was subsequently infilled.

4. Risk assessment

Problems with RAAC roof planks have been known about since the early 1990s. In many buildings, the planks have been replaced with alternative structural roofs or the spans have been shortened by the introduction of secondary supports, but others will remain and may pose risks.

The partial collapse that occurred in 2018 was at a weekend so the school was fortunately unoccupied. In structural safety terms it was a near miss. Similarly, in the case of the **Edinburgh School masonry collapse in 2016>**, this occurred in the early morning when no pupils were present. In either case, the consequences could have been more severe, possibly resulting in injuries or fatalities.

There is therefore a risk, although its extent is uncertain. The risk must be identified by locating buildings where RAAC planks are present and assessing their condition and structural adequacy. If there is doubt about the structural adequacy of the planks, then it is recommended that consideration is given to their replacement.

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5. Identification/inspection of RAAC planks

There is no central register of buildings with RAAC roof planks (and/or floor and wall panels), so identification will depend upon local knowledge and individual inspections. There are consulting engineers who have worked on such buildings over the years and who have specialised knowledge of the problems and their solutions. **The Institution of Structural Engineers>** may be able to help in locating these. There is a need to risk assess, suitably plan, and then develop a safe system of work for all identification and inspection work.

The steps for an owner/building manager to take in identifying RAAC planks would include:

- Note that RAAC planks were used for the construction of flat roofs in the 1960-80s, so buildings (or extensions) pre-dating or post-dating this period are unlikely to be affected;
- Ask whether any similar buildings in the area are known to have RAAC roof planks;
- Access any records relating to construction to see if RAAC is mentioned, although an absence of identification on records does not exclude the possibility of the material being present;
- If the construction type of a roof is not known and could potentially be RAAC planks, then the roof should be inspected, and measures put in place to manage the risk e.g. temporary propping of the roof.

The 1996 **BRE Information Paper IP 10/96 - Reinforced autoclaved aerated concrete planks designed before 1980>** outlines a preliminary inspection procedure. This was to inspect the soffit of possible RAAC planks for indications of excessive deflection and to inspect roofs from above for signs of rainwater ponding. If these signs are present, then the structural roof planks may be of RAAC construction or it could be another form of construction that is not behaving as well as might be expected. Inspections from above should be done from a place of safety e.g. nearby vantage point, drone, mobile elevated work platform (MEWP) or scaffolding.

If planks are visible from the underside, then it is important to inspect these for warning signs which include visible cracks (particularly in the vicinity of the end supports), evidence of water ingress, rust staining or spalling. Consideration should be given to conducting a small intrusive drill sample to assist the inspection.

If it is suspected that RAAC planks are present, then an appropriately experienced Chartered Structural Engineer or Chartered Building Surveyor should be appointed when conducting identification and inspection work.

6. Managing RAAC planks

If RAAC planks have been identified, the steps for an owner/ building manager to take would include:

- Conduct a risk assessment. The use of space beneath a roof will affect the risk assessment e.g. a classroom will be a higher risk than a store. If there is doubt about the structural adequacy of the planks and/or there is evidence of water ingress, then it is recommended that consideration is given to their replacement. The use of the space beneath the roof may need to be discontinued until the roof has been strengthened or replaced.
- Consider the long-term plan for the RAAC roof. In some cases, the life span of the roof will have come to an end and replacement will be necessary. In other cases, it may be felt that regular inspection is merited and that records are kept so that the significance of any changes in behaviour can be readily assessed;
- Check with maintenance staff, facilities managers, contractors and others who have access to the building to ask about roof ponding, roof leaks, cracks on the underside of flat roofs or other signs of deterioration;
- Check with the same people about re-surfacing that may have taken place as this could affect the load on a roof. This includes checking if a levelling compound was used to re-create the roof fall prior to replacing waterproofing;
- Check the colour of the roof surfacing - if it is black then this may indicate enhanced sensitivity to thermal effects;
- Ensure that all staff know to report any leaks, cracks and or other potential defect issues;
- If there are sudden changes such as audible cracking sounds or greatly increased water ingress, or observable deflection, then the area should be immediately closed off. This would apply to any form of structure;
- Any such observations could be warning signs and should merit expert attention from an appropriately experienced Chartered Structural Engineer or Chartered Building Surveyor.

Warning signs

- Significant cracking and disruption of the planks near the support;
- Any planks have deflected more than 1/100 of the span, or a significant number of planks have deflections approaching this magnitude;
- A number of the planks have very small bearing widths (less than 40mm);
- The roof has been re-surfaced since original construction; This is particularly an issue if the load has been increased or the re-surfacing has a black finish and the previous surface did not;
- There is significant ponding on the roof;
- The roof is leaking or has leaked in the past.

As advised by BRE and modified by the experience of the 2018 collapse, additional steps for an appropriately experienced Chartered Structural Engineer or Chartered Building Surveyor to take would include:

- Make an examination in accordance with the principles in the IStructE publication **Appraisal of existing structures (Third edition)›**;
- Measure deflections where there is evidence of significant differential deflection between adjacent planks (20mm) or where there are excessive deflections (greater than 1/200th of the span);
- Note any cracking on the soffits, check the condition of planks in the vicinity of the support, and the width of the support bearings;
- In the light of the 2018 collapse, pay particular attention to any shear cracks near the supports;
- Check for any signs of water penetration or reinforcement corrosion;
- Use a covermeter to check the provision of transverse and longitudinal reinforcement and note any appreciable inconsistencies between planks. The transverse reinforcement is normally spaced closer towards the support. However, occasionally cut planks were used and therefore the spacing of the transverse reinforcement at the support would be greater. Therefore, the risk of insufficient provision of transverse reinforcement may be greater with cut planks;
- Check whether tension reinforcement extends to the end of the visible planks;
- Check whether tension reinforcement is present on the bottom of planks over continuous supports where sagging may occur due to thermal effects;
- Consider what collapse mechanisms are possible before assuming that adequate warning will be given;
- Confirm the composition of the planks by sampling and laboratory testing.

If there is doubt about the structural adequacy of the planks and/or there is evidence of water ingress, then it is recommended that consideration is given to their replacement.

Sight must not be lost of the fact that the 2018 collapse was sudden with very little noticeable warning. This is indicative of shear failure in cementitious materials and can only be protected against by knowing that there is sufficient shear resistance in the material, the reinforcement, or both.

In a **reminder›**, the LGA and the DfE stated that the condition of all buildings should be regularly monitored, taking a risk-based approach that gives due deliberation to the use of the building with consideration given to the possible impact of reduced maintenance.

Sight must not be lost of the fact that the 2018 collapse was sudden with very little noticeable warning. This is indicative of shear failure in cementitious materials and can only be protected against by knowing that there is sufficient shear resistance in the material, the reinforcement, or both.

References

1. **IP 10/96 - Reinforced autoclaved aerated concrete planks designed before 1980›**, BRE, 1996.
2. **IP 7/02 - Reinforced autoclaved aerated concrete planks - test results, assessment and design›**, BRE, 2002.
3. **Twelfth Report of SCOSS›**, Structural-Safety, 1999.

INFORMATION

What is SCOSS?

SCOSS stands for Standing Committee on Structural Safety and was established in 1976 to maintain a continuing review of building and civil engineering matters affecting the safety of structures.

SCOSS collects data for public sources and CROSS reports on all aspects of the safety of structures.

If they consider that unacceptable risk exists or is likely to arise in the future, SCOSS then publish Alerts or Topic Papers to inform the industry of the risks identified.

All SCOSS publications are free to read on the **Structural-Safety website>**.

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