Lightweight, Autoclaved, Aerated, Cellular Concrete Roof Panels (LAACCRP): Structural and Re-Roofing Problems

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INTRODUCTION

WHILE DURABILITY OF CONSTRUCTION PRODUCTS IS A SUBJECT OF INCREASING importance, it has generally been accepted that roof decks should last for the life of the building. The degradation of Lightweight, Autoclaved, Aerated, Cellular concrete roof panels (LAACCRP) is fostering new interest and concerns. The density of the material is approximately 31 to 37 lbs./ft.^{3}, which is 20 to 25 percent that of normal reinforced concrete. The compressive strength of the material was originally specified to be 450 psi, which represents 15 percent of the compressive strength of normal concrete of 3000 psi.

This product was manufactured in Canada between 1955 and 1972. The principal ingredients of LAACCRP are pulverized sand, portland cement and aluminum powder. The chemical reaction between these ingredients and water results in a mineral cellular product which was typically formed into slabs of various lengths and thicknesses. The panels were reinforced with smooth rods sized to carry the required roof design loads of the day. (*Figure 1*)

LAACCRPs are found today in many schools, hospitals, commercial and light industrial buildings and are easily recognizable due to their comparative light weight and because the panels are easily scored by fingernail. Main issues regarding this material are structural integrity, durability, safety and re-roofing concerns. There have been known cases of failure of these types of roofing panels, so we believe the topic to be very significant. This article discusses various findings and experiences from working on a great many buildings with these panels as well as provides some recommendations regarding evaluation and re-roofing.

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Background

In the 1950s, LAACCRPs were quite a revolutionary product in Canada. They had many advantages and were quite readily accepted in the market place. Features of the product that made it quite desirable to building owners and design teams include the following:

- Reasonably good insulating material. Manufacturers indicated that roofing insulation was not required (in many applications) with the use of this product, therefore reducing construction costs.
- Speed of construction due to the lightweight nature of the pre-formed panels.
- Reasonably good acoustical properties.
- Good bonding of asphalt directly to the surface for ease of roofing, thus reducing construction costs.
- The material has a reasonable fire rating.

Factors Impacting LAACCRP Durability and Integrity

The following is a summary of some main issues facing building owners and design teams:

1. Absorption of Moisture

Due to its porous composition, one identified problem with LAACCRP is the absorption of moisture from within the building and from water ingression due to roof leaks. This is especially so in high humidity environments such as swimming pool structures and certain manufacturing plants. The structural concern is one of loss of integrity and durability. The LAACCRP, forming the structural roofing system, should be expected to perform for at least the design life of the building with no maintenance or repairs. The ingression of

moisture into the material could lead to the corrosion of the steel reinforcement leading to spalling of the material.

Another issue is the ingression of moisture followed by condensation and periods of freezing and thawing as is common in Canada. It was previously noted that roofing systems on LAACCRP were often installed without insulation, thus the dew point fell within the depth of the panels. This practice is believed to be quite detrimental to the durability and performance of roof panels due to the resulting spalling and delaminations.

Properly designed and constructed roofing assemblies would include a vapor barrier, but experience has shown time and again little regard for the vapor barrier in roofing assemblies of this vintage, thus facilitating the ingression of moisture from within the building.

For various reasons, LAACCRP are known to experience a reduction in their compressive strength with age. This is very significant as a reduction in compressive strength will result in a reduction of the panel's load-carrying capabilities. The ingression of moisture is thought to be a contributing factor in the reduction of the compressive strength. With the reduced capacity, the panels may no longer be able to resist the imposed live loads such as snow loading, especially at locations adjacent to high roofs due to the snow piling.

2. Fastener Loads

Due to the generally weak properties of the panel's material (specified compressive strength of 450 psi), mechanical fasteners can not be depended upon to withstand any significant loading conditions such as lateral loading due to wind or uplift forces due to negative pressure conditions.

3. Impact Loading and Vibrations

It is believed that impact loading and vibrations have a negative impact on the performance of the panels. LAACCRPs were generally reinforced with smooth steel rods of various diameters, depending on the span, depth and loading conditions they were subjected to. Impact and vibrations are believed to reduce the bond between the cellular lightweight material and the smooth steel rods. This creates a condition of reduced contribution of the steel reinforcement towards the load carrying capabilities of the panels.

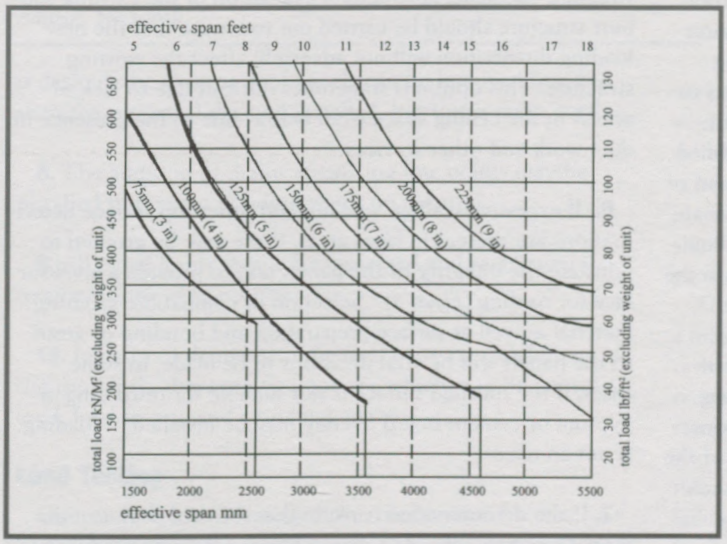

Figure 1: This chart is the LAACCRP manufacturer's load span table.

4. Poor Construction Practices

Mounting of plumbing pipes, ductwork and suspended ceilings from the panel's bottom reinforcing rods (exposed by localized chipping) serves to provide additional loading to the panels which they were not intended to support. There should be no elements directly supported by the panels. Rather, these items should be supported directly from structural steel beams or secondary steel elements designed for this purpose.

Another common poor construction practice was the cutting or coring of holes through the LAACCRP for the installation of ducts, drains and the like without reinforcing the panels around the openings from below.

The re-saturation of existing roofing systems with LAACCRP decks serves to add load, increase deflection, increase water ponding and reduce the live load carrying capacity of the roof structure. This is really a compounding problem.

Due to the ineffective anchoring or fixing of the panels on steel beams with tie wires, (in some cases) the condition of panel slippage from its support is also a common one. This may lead to the direct failure or collapse of panels or they may just rotate at the one support. As a minimum, this condition may lead to the direct tearing or splitting of the roofing membrane.

During re-roofing operations on roofs with LAACCRP decks, damage to the top surface of the panels is often the result during the removal of the existing roofing and vapor barriers. It is often very difficult to avoid the resultant scaling of the top surface due to the good embedment of bitumen into the pores of the panels and because of the weak lightweight nature of the material. Scaling to a depth of 13 mm to 20 mm is often the result. It is evident that this practice has a negative impact on the performance of the panels and every precaution must be taken during re-roofing operations to avoid such damage *(Figure 2)*.

5. Excessive Deflections

Excessive deflections are also the result of the conditions described above in items 1, 3, and 4. Differential deflection of the panels serves to create conditions of ponding water at low spots on the roof.

This is a significant loading condition, as 1" of water represents 5psf, thus reducing the live-load carrying capacity of the roof structure by an equal amount. This situation can be rectified by the installation of additional roof drains at these low spots. Also, if left unaltered, this condition of ponding water is known to be a contributor to the premature failure of roofing systems.

Figure 2: LAACCRP roof panels as viewed upon the removal of the existing roofing. Note the surface deterioration.

Figure 3: LAACCRP as viewed after the grouting of the surface deterioration. This section is now ready for priming and new roofing assembly.

Re-Roofing and Structural Recommendations

As indicated in the previous section, the issues facing building owners and design teams regarding LAACCRP decking are complex and demanding. In 1990, various circumstances, including the failure of panels, excessive deteriorations, roofing problems and cost thereof led the Ministry of Education in Ontario to mandate a review of the schools containing these roof panels. The mandate given by the Ministry was to have school boards make a determination of whether roof panels are present and if so, to retain the services of qualified professionals to review, monitor and evaluate the condition of such. This mandate is easily made, but the solutions associated with such may not be so easily accomplished. The following are some of the steps which may be taken to deal with the issues previously described:

1. Identification and recording the locations and areas of LAACCRP is a good first step. This will serve the building owner in maintaining an inventory of the affected locations and any maintenance and repairs completed. Inspection of the panels can be very difficult as only the bottom of the panels can be reviewed by lifting suspended ceiling tiles. If fixed ceilings are present, inspection is made more difficult as access hatches will be required. During an inspection program, the top surface of the panels is rarely inspected because of the existing roofing. Very often, the most severe problems are encountered on the top surface only.

2. The top surface of the panels is usually inspected only during the re-roofing of such. If the owner chooses separate consultants for roofing and LAACCRP, a coordinated effort must be made by the building owner to ensure that the professionals engaged for LAACCRP inspection and evaluation are on site during the stripping of the existing roof.

3. Individual panels may be removed and replaced with adequate steel decking welded to the adjacent steel beams and insulated over top to provide a level surface to match the depth of the existing panels (*Figure 5*). The vapor barrier will be required to extend from the top surface of the roof deck and on to the steel deck. All overlaps should be continuously sealed.

4. If localized areas of panels are found to be in generally weakened and poor condition due to excessive scaling, spalling or delamination, these may be left in place and reinforced with an adequate steel plate placed over top spanning onto adjacent steel supports. This will serve to ensure that the existing roof panels will no longer be required to retain any loading, except for their own weight.

5. Weakened LAACCRP decks may also be reinforced by the installation of structural steel from below. New steel channels (angles or beams as required) can be welded to adjacent existing steel support beams at mid point (or third points) of the LAACCRP as required. This procedure will serve to reduce the span length of the panels, decreasing the imposed forces on the panels and rendering the roof structure adequate. A structural evaluation of the existing support structure should be carried out to ensure that the new loading distribution will not adversely affect the existing structure. This option is sometimes difficult due to lack of access in the ceiling space from below, due to the presence of duct work and other services.

6. If excessive scaling, spalling and other top surface deteriorations are present in large areas, these may be grouted to reinstate the integrity of the panels and to provide a level surface for roofing (*Figure 2*). Selection of compatible grouting material as well as surface preparation and bonding of grout to the panels will be vital decisions to be made. In some cases, if the finished surface is not suitable for re-roofing, a gypsum or cement board overlay may be installed, if loading is not an issue.

7. If the determination is made that the roof deck can no longer resist the imposed design loads, a new structural roof will be required. It is possible to provide a new steel deck over the top of the existing LAACCRP decking (*Figure 4*). Or,

Figure 4: The LAACCRP roof deck was found to be unable to resist the snow loading. A new structural system is being installed, consisting of 25 mm deep x 25mm wide steel plates welded to the supporting steel structure below accessed by drilling cores through the LAACCRP. New 75mm deep corrugated steel decking is being fusion welded to the plates and will span the required 2900 mm, which is the span between the new plates. Although the LAACCRP is not being removed, it will no longer be required to resist any loading other than its own weight.

Figure 5: LAACCRP roof panels found to be severely deteriorated have been removed and replaced with new 38 mm deep corrugated steel decking. The new steel deck is fusion welded to the existing steel beams and anchored to the exterior masonry block wall.

if desired, the existing roof panels can be removed first and then the new steel decking installed, but this is more costly.

8. The addition of drains at existing low points may be installed to prevent ponding water on the roof.

9. All panel joints should be inspected and re-grouted if required prior to re-roofing.

10. In cases of doubt as to the load carrying capabilities of the roof deck, there are two options which may be considered: load testing and structural analysis.

Load Testing

One is on-site load testing of the roof section by placing a known loading on the roof by means of a designated depth of water in a pool-like apparatus. Scaffolding with dial gauges (for the measurement of deflections) will have to be set up under the roof. The known loading on the roof should be the required live load (snow loading plus rain accumulation) for the region multiplied by 1.5 (safety factor). If the results are positive, the load is safely carried with the deflection measured at less than L/360 (panel span /360). If the result is not positive, the deflections will be excessive (>L/360) and if not careful, the LAACCRP panels may fail. Plywood should be placed on the scaffolding frames below the roof just in case of this eventuality.

This is the preferred method for the determination of the load carrying capacity of a roof structure. The results are very indicative, inspire confidence and there is no question of the results presented. For various reasons, this method is not often authorized by the building owners.

Structural Analysis

To determine the capacity of LAACCRP panels, we must have an understanding of the manner in which the material behaves under conditions of loading. Attempts have been made to evaluate the capacity by means of an analogy to reinforced concrete design. The general principles are the same; however, there are important differences such as the bond between the smooth steel rods in LAACCRP and the deformed steel bars in concrete. Another significant issue is the vast difference in the densities of the two materials. This density of LAACCRP is between 31 lbs./ft.^{3} and 37 lbs./ft.^{3}. The density of normal reinforced concrete is 150 lbs./ft.^{3} and the density of "lightweight concrete" as defined in the Concrete Design Code is 95 lbs./ft.^{3}. Furthermore, the Concrete Design Code specifies that the formulations developed should not be used for concrete materials of densities less than 95 lbs./ft.^{3}, so this means that the results obtained by use of the formulations developed for reinforced concrete design should not be solely relied upon, in our opinion.

Our experience with this type of analysis revealed a very important feature of LAACCRP which qualified professionals should be aware of and keep in mind. The elastic design of reinforced concrete as it pertains to a simple beam is based on the general principle that reinforcing steel be placed at the bottom mid-span of the section to resist the tensile forces, where they are at a maximum and the concrete provides no contribution to the resistance of tensile forces.

At mid-span, top of section, where compressive forces are at a maximum, the concrete is the primary contributor to the resistance of the compressive forces and steel is added only if required. In good design and as specified by today's code, the steel reinforcement will yield prior to achieving the maximum allowable stress in the concrete. This is because of the respective failure modes of the two materials, steel and concrete. If failure of a section is due to tensile forces, it will be resisted by the steel and failure will be precluded by excessive deflections which will serve as a warning. If failure is by compres-

sive stresses, the primary contributor to this resistance is concrete and failure by concrete compression is immediate and without warning. Due to its very low compressive strength (450 psi specified and could reduce by 70 percent in our experience), failure will almost always be by compressive stresses, which means failure is sudden and without warning.

Conclusion

Although LAACCRP has been around for many years, we must learn how to deal with this material in a proper manner and give it the respect it requires. The issues are many and are integrated and related. One thing is certain—building owners do not expect to treat their roof structure as a regular maintenance item. The roofing consultant is usually responsible for the roof deck so far as the roofing application is concerned. Ideally, the roofing consultant will be retained to investigate and deal with all aspects including the structural deck issues. If not, a strong, coordinated effort must be made by roofing and panel consultants and mandated by building owners. Simple and incomplete reviews and inspections may meet the budgetary constraints of owners but provide very limited information required to make informed decisions which impact the safety of occupants.

It is difficult enough for most building owners to ensure a minimum program of maintenance for their roofing system, such as ensuring that drains are kept clear and debris is removed from the roof. It is not expected that one of the main structural components of a building has to be reviewed, inspected and evaluated every few years. During programs of re-roofing, qualified professionals are faced with the decision of whether to re-roof over the existing LAACCRP decks, remove the decking and install a new roof deck, or install a new roof deck over the existing LAACCRP decking. The decision would be a simple one if economics was not entered into the equation, but of course it is. Load testing poses logistical and building use issues with owners and is relatively costly. Structural analysis of LAACCRP leaves questions and uncertainty. Clearly, additional on-site and laboratory research is vital to aid in the establishment of general evaluation criteria.

About The Author

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Flexible Membrane Sales Growing

According to a recent statistical report released by SPRI, the trade association representing sheet membrane and component suppliers to the commercial roofing industry, the flexible roof membrane market continues to expand.

Shipments for such materials were up 8% in 1997 over 1996, with the highest year-to-date gains registered by thermoplastics, with a total increase of 17 percent.

Thermoset membrane shipments increased 25% to the West, 19% to the Northeast, and 16% to the North Central region.

Significant double-digit growth was also reported in the South in the ballasted market, with a 36 percent gain over that of 1996. For SBS modified bitumen, the strongest increases were in the West, where shipments rose 27 percent.