A Method and Apparatus for Evenly Dispensing Measured Acrylic Resin to the Upper Side of a Wood Lath and Plaster Ceiling Assembly Where Access is Limited

Rod Stewart and Greg McEwan

Abstract

The reattachment of loose plaster to its wood lath substrate is a common requirement in historic building rehabilitation. Typically, but not always, subject ceilings carry some important decoration that would be lost if the ceiling was allowed to fail. The most common treatment is usually referred to as consolidation — the making whole of the assembly by the addition of a material that binds the components.

The most common consolidation process used for plaster ceilings consists of saturating the upper side of the plaster and lath assembly with various dilutions of an acrylic resin that has the characteristics required to somewhat penetrate the porous plaster, encapsulate it, and essentially bind it to the wood lath structure that holds it up. This treatment is non-reversible. In a typical project, the consolidant is pumped up from the ground and applied from the attic side of a ceiling by means of a network of sprayers. Access to the treatment face is simply a matter of getting there and cleaning up the debris that has accumulated over the century or so since construction.

This paper describes an advanced method and apparatus for achieving the same treatment result in situations where no access is possible from above, and where access through the face of the ceiling is constrained by the need to protect known or anticipated decoration. The pneumatic apparatus consists of a 6.25 mm-hollow piston that rises and falls within the joist cavity and through which precisely measured shots of resin can be delivered with predictable results.

Introduction

The reattachment of loose plaster to its wood lath substrate is a common requirement in historic building rehabilitation. Typically but not always, subject ceilings carry some important decoration that would be lost if the ceiling was allowed to fail.

The conservation treatment advocated is usually referred to as consolidation - the making whole of the assembly by the addition of a material that binds the ingredient components. The treatment effectively converts the suspended plaster ceiling from being one that is loosely hung by plaster lugs and keys to one that is adhered to the wood lath substrate to which it was originally applied. Unfortunately this treatment is not reversible. None of a host of treatments used to less advantage for the same purpose is reversible. Neither, for the record, is ceiling collapse.

In 1980, the late Morgan W. Phillips published a seminal paper in which he reported on experimental work completed between 1976 and 1980 that was concerned with "injecting specially formulated acrylic based adhesives into the spaces between lath and plaster, through holes drilled either through the plaster or where the reverse side is accessible, through the laths or other substrate." (Phillips 1980, p.41)

The paper provided several formulas for adhesives using Rohm and Haas resins Rhoplex MC 76 and Rhoplex 1950 along with fillers of different particle sizes including lime or chalk, micro spheres and the interesting shrinkage compensator petroleum coke also known as fluid coke. The paper also presented formulas for chemically thickening the resins to produce a thixotropic or more correctly pseudo plastic adhesive that could be injected through fine orifices and which remained in place when applied. Some of the unfilled mixtures have gained wide acceptance and there is a commercially available product called Big Wally's Plaster Magic that is similar to Phillips' unfilled chemically thickened adhesive.

The Phillips paper noted the importance of using a non-shrinking material where voids greater than about 4 mm occur. He noted that by employing the space that exists between the plaster and lath, the restorer was "providing a continuous bond ...that distributes the load imposed by the heavy ceiling plaster over the maximum area of the reverse side of the plaster, thus reducing the tensile stress on any one portion of the plaster" (Phillips 1980, p.41). Phillips qualified his offering by saying that it had not been extensively tested.

One basic observation about how plaster functions and fails is that "as built" there is no significant adhesion between the plaster and its wood lath substrate. This is uniformly found to be the case, but no studies have been discovered to confirm that it is intentional. It does seem logical that in wood frame situations, that a loose flexible assembly would be more resistant to damage than a rigid monolithic system. In any case, whatever connection there might have been at the time of installation, plaster is never found to be adhered to its wood substrate – it is always loosely supported by the keys and lugs formed during installation. The entire assembly of flat plaster in three coats up to 25 mm or more in thickness and weighing as much as 20 kg / m^2 is suspended by the keys and lugs that are formed when excess plaster in the brown coat is forced between the laths. (See Figure 1).

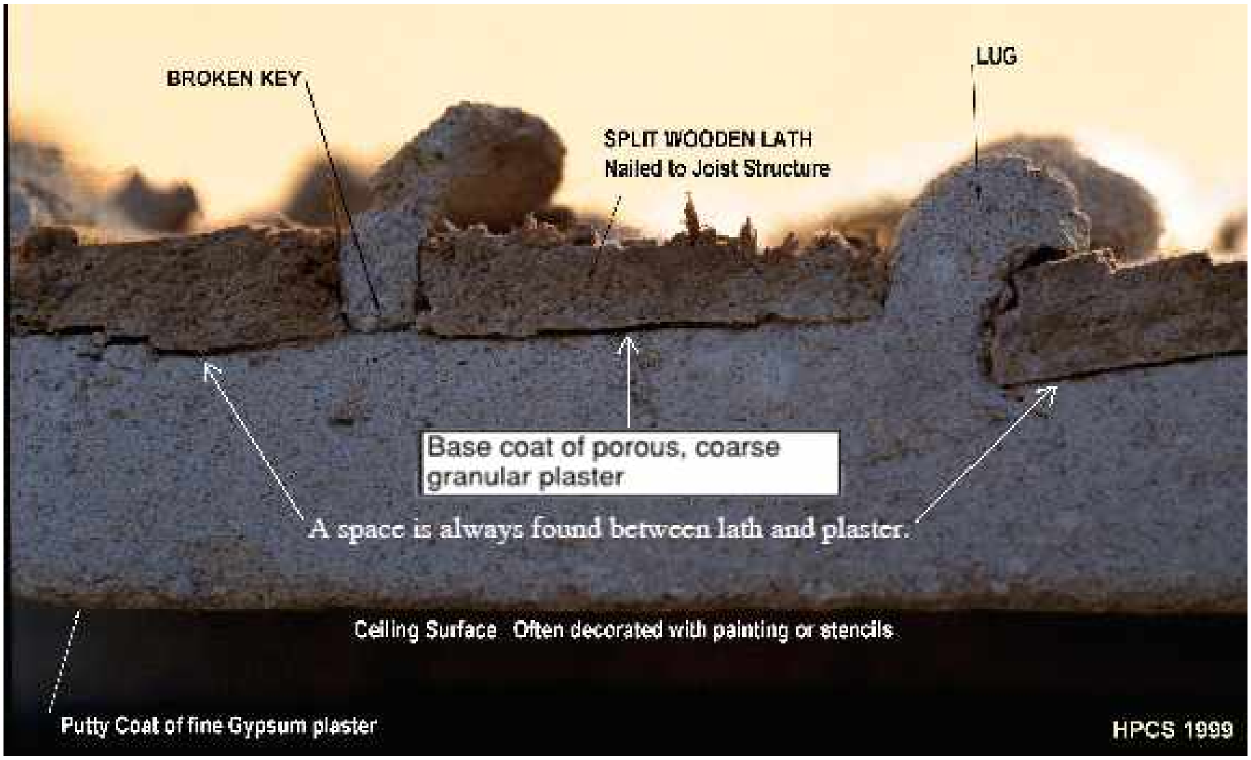

Figure 1: Typical Cross-section of a Wood Lath and Plaster Ceiling

The practice of plaster conservation is the practice of developing and using different methods of converting suspended "un-adhered" plaster systems from that condition to being adhered one way or another to their respective substrates with an appropriate adhesive.

This paper deals with the use of an unfilled adhesive suitable for the specific situation where the gap between lath and plaster is minimal – less than 4 mm, and where access to the upper side of the plaster for conventional flooding is not possible. These are cases where the detached plaster has not yet fallen further than 4 mm or where it has been raised on temporarily supports to the level where the use of an unfilled adhesive susceptible to shrinkage on curing is appropriate.

Sometimes direct access to the upper side of a ceiling is not possible because heavy occupancy loads in the building prevent the extended disruption that occurs with opening up floor and ceiling cavities. Sometimes it is the case that finished floors in rooms above the subject plaster are valuable and cannot be disturbed. In occupied public buildings, the condition is more likely to be one of restricted access than one of unfettered access.

Temporary support of all flat ceiling surfaces during treatment
In all cases, however, after it has been determined that treatment is required, a decision has to be made as to what temporary support if any is needed to protect the ceiling during the treatment. The current practice in most situations involves the use of a "dead man" prop to support padded surfaces against the subject ceiling. A "dead man" is typically a stiff timber that is slightly longer than the height of the room from floor to ceiling. In a high-ceilinged room, such a "dead man"

prop may be deployed from a scaffold platform. It is usually used to support a padded surface, typically plywood, against the ceiling. There are drawbacks to this approach.

- It is not very accurate in terms of how much pressure can be applied.
- The surface being protected is ultimately concealed from view during the protection period.
- The installation of the "dead man" often causes damage.
- The removal of the "dead man" is required in order to actually work on the surface.
- Sometimes the ceiling collapses at this point.

A more precise method of protecting important plaster ceilings prior to and during treatment involves the use of many small micro jacks attached to 50 mm pipes that are supported above a conventional scaffolding system that will ultimately be used during the conservation of the decoration on the ceiling. (See Figure 2).

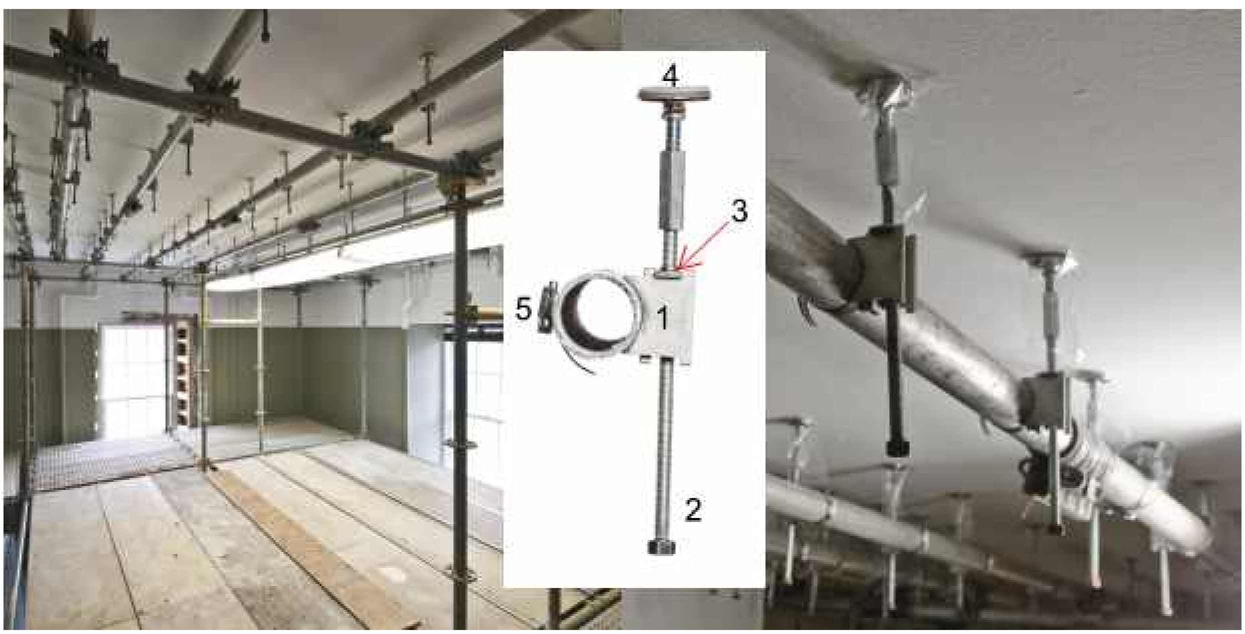

Figure 2: The Temporary Plaster Support System Deployed at the Colonial Building in St. John's, Newfoundland, summer 2011.

This jacking system permits:

- as many or as few direct points of contact with the plaster as are needed to provide the required support;
- the application of jacking pressure to the surface without abrading the surface;
- complete flexibility of jacking point contact locations so that sensitive painted areas can be avoided;

- grouping of jacking points so that whole planes of plaster can be manipulated and coaxed back into better locations as required; and
- a clear view and unobstructed access to the surface during treatment.

This system was used in the summer of 2011 at the Colonial Building in St. John's Newfoundland. The Colonial Building is an 1853 Greek revival building with large ceremonial rooms. It was built as the seat of government in Newfoundland until it was replaced in 1958. It is currently undergoing extensive restoration and will ultimately become the Museum of Newfoundland History.

For ceilings of national or regionally significant decoration, this temporary support system offers a precise alternative to other methods. At the Colonial Building, two hundred and fifty micro jacks were deployed in each of eleven rooms with areas of about 32 square meters.

Conventional access consolidation by flooding
The conventional consolidation process used when access to the upper surface of the lath and plaster ceiling is available consists of first meticulously testing keys and lugs to remove broken or non-functioning ones, and second, saturating the upper side of the plaster and lath assembly with measured amounts of various dilutions of acrylic resin. (See Figure 3.) The basic resin in Phillips formulas was Rhoplex MC 76, the characteristics of which were that it had high solids content and relatively low viscosity. Other resins with similar characteristics have been used successfully. Specifically, Acrynol NX 4623 is appropriate for this purpose.

Figure 3: Left: Technician Testing Keys and Right: Technician Applying Dilute Resin

The testing and removal of broken keys is desirable in order to expose as much raw plaster surface as possible to the potential for absorption of the consolidating resin. Technicians have to be careful not to break off previously unbroken keys in this part of the operation.

The spray application is typically two or three coats of material, the second following the first while it is still wet. The first application is often as diluted as 15% resin. The preferred solvent is Special Denatured Alcohol 9 (SDAG 9), but in cases where adequate ventilation cannot be guaranteed, water can be used.

The diluted resin will somewhat penetrate the porous plaster, encapsulate it, and essentially bind it to the wood lath structure that holds it up. One of the remarkably beneficial features of these low viscosity, high solids resins is how well they penetrate into fine cracks and crevices in the plaster, essentially going where they are needed. The flooding technique guarantees that the resin finds its way into the space between the lath and plaster.

New Developments in Materials and Apparatus

A great challenge was presented in 2005 with the commission to study the condition of 400 plaster ceilings in the former City Hall in Toronto. Old City Hall, designed by noted architect E. J. Lennox and completed in 1899, is a National Historic Site that has been converted for use as the hub of legal interface between the public and the judiciary in Toronto, with over 22 courts in action six days per week, twelve hours per day. The study was preparatory to the installation of a new heating, ventilation and air conditioning system throughout the building. There is, as a result of that study, a list of 150 heritage character defining wood lath and plaster ceilings to be consolidated and protected in a project that will begin in the fall of 2011 and run for about three years.

Conservation of plaster ceilings takes on a decidedly difficult turn when the requirements are that:

- There is no access to the upper side of the plaster and lath between the joists.
- Work must be done between 8:00 p.m. and 6:00 a.m.
- All areas must be returned to full beneficial use of the tenant each day after any work session.
- All work must be executed by members of the International Union of Painters and Allied Trades.

For this specific project and other potentially similar applications, the authors have developed a special apparatus designed to evenly apply a precisely metered amount of consolidation polymer resin to the floor of a joist cavity, such that it coats the lath and penetrates the plaster beneath. The apparatus, called a Plaster Conservation Polymer Applicator (PCPA), does this by injecting the material through a series of 6 mm holes drilled in the surface of the ceiling. (See Figure 4).

The intent is to accomplish approximately what occurs in the conventional consolidation process with the constraint that there is no access to view the work in progress. Floors above the rooms cannot be taken up and obviously ceilings cannot be overly disturbed. This treatment will not have the advantage of the use of the filled formula adhesives developed by Philips. Close inspection and hand-testing of the plaster keys will not take place. The efficacy of the treatment will depend entirely on the flooding of the space between lath and plaster with multiple applications of the consolidant water-diluted Acrynol NX 6423. SDAG9 will not be used for reasons of fire safety.

Old City Hall is a very regular building, predictably built according to the architectural drawings that are on record. Joist direction and spacing are known. The location of herringbone bridging can be predicted and confirmed. The authors have seen several of this building's plaster ceilings in a collapsed state and have had opportunities to conduct porosity trials on the plaster. This background work has all been done.

It will not be possible to actually witness the application of resin to surface. The entire application will be done without direct access to view the work in progress. However, as in a regular consolidation treatment, when the measured amount of material is accurately placed and allowed to seep between the plaster and wood lath, it polymerizes there and as it does so, it re-secures the plaster to the lath. That is the prediction on which the trials conducted in the summer of 2011at the Colonial Building are based. Test cuts will be used to confirm the results.

Testing the apparatus in St. John's NL in the summer of 2011
The apparatus designed to do this work was tested earlier this summer at the Colonial Building in St. John's, Newfoundland.

Description of the apparatus function
The PCPA has a small diameter applicator wand that is inserted vertically into the joist cavity through a 7 mm diameter hole either in the floor above or through the plaster in the ceiling below.

An interchangeable nozzle on the end of the wand has its outlet at some angle,(nozzle angles in the prototype apparatus ranged from 5, 10 and 15 degrees) below the horizontal, thereby directing a stream of polymer at the floor of the joist cavity.

The wand reciprocates up and down. If the wand has been inserted up from below as at the Colonial Building, when it is retracted, the nozzle outlet is close to the floor of the joist cavity. When it starts to apply the consolidant Acrynol NX 6423, the area closest to the wand is coated first. As the wand extends vertically, the flow is directed outward along the floor of the cavity.

For every measured unit of stroke, the apparatus delivers a precise amount of consolidant. This apparatus is sized so that 25 mm of stroke delivers 40 ml of consolidant, regardless of dilution. Coverage of the area on the floor of the joist cavity can therefore be carefully controlled.

Once the conservator has determined the appropriate volume of consolidant to be applied and decided on the sequence of applications of different dilutions to accomplish the best penetration result for the given area of ceiling plaster, the information is dialed up on the apparatus and application can begin.

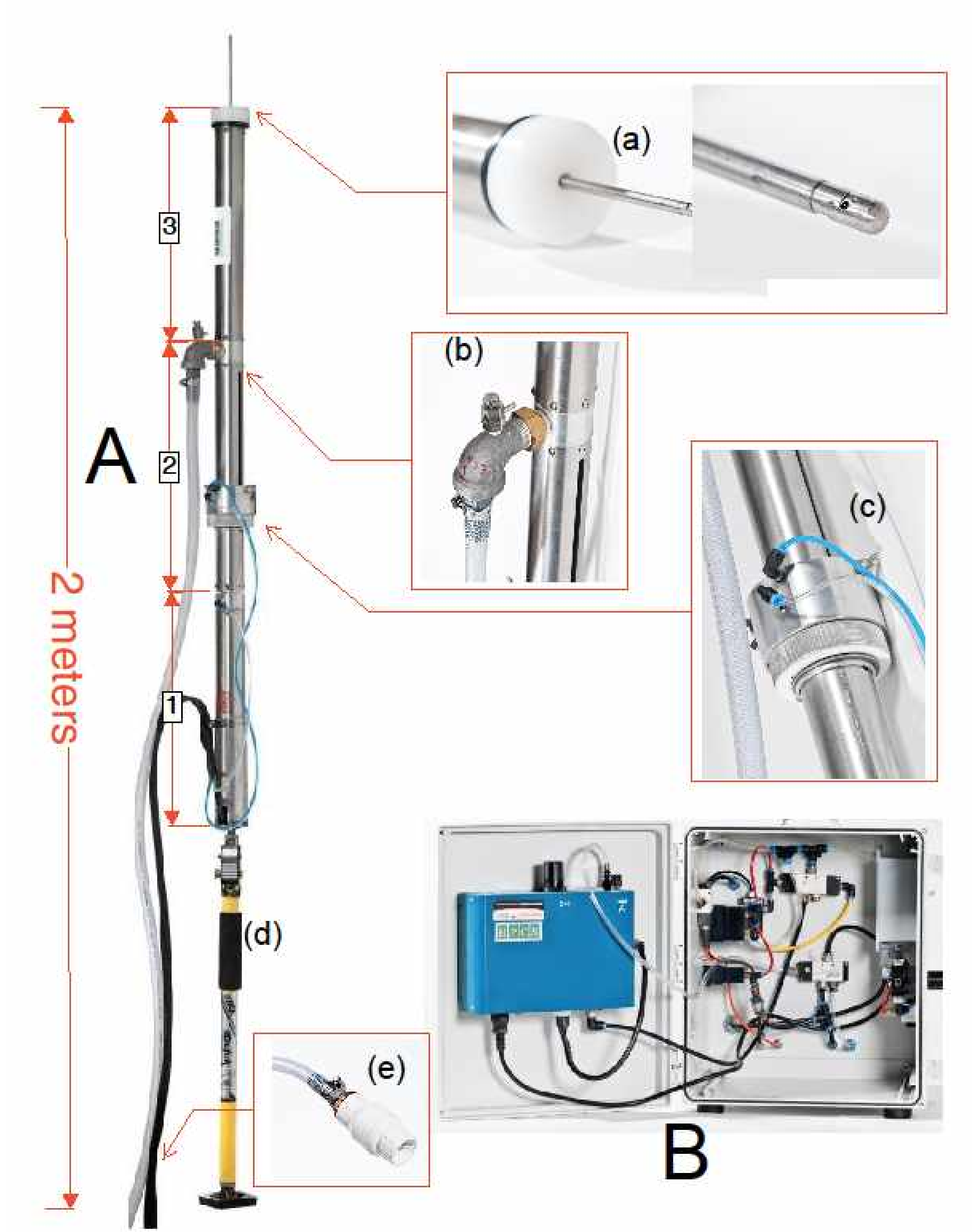

Figure 4: The Plaster Conservation Polymer Applicator (PCPA) The PCPA consists of two main parts…the applicator “A” and the programmable controller unit “B”.

The two principle parts of the apparatus are the 2 m long applicator marked “A” in Figure 6 at left, and the controller marked “B” at the bottom.

In the same figure,

(a) is the dispensing wand with a close-up view of the tip;

(b) is the material inlet port with a bleed valve;

(c) is the rotating On/Off control and the mechanism that sets the length of each stroke;

(d) is a ratchet jack used to extend the length of the applicator to fit the circumstances;

(e) is a foot valve attached to the reservoir end of the supply line.

The applicator

The applicator consists of three connected parts:

1 is a non-rotating double-acting air cylinder,

2 is a divorcing stroke-length control section, and at its end,

3 is a metering pump and wand.

The non-rotation feature ensures that the wand always sprays in a known direction.

The metering pump is a single acting device, meaning that it dispenses only on the rod extension part of the cycle. There is one valve on the metering piston and one on the wand. They are opposed such that when one is open the other is closed. When the piston is in its “home” position, the piston is at the bottom of the metering chamber and its valve is open. The metering chamber is filled with liquid and the valve on the wand is closed.

To dispense, the air cylinder drive rod extends, the metering piston valve closes as the piston is driven into the metering chamber. At the same time, the valve on the wand opens allowing the trapped fluid in the metering chamber to be extruded from its nozzle. The amount of liquid dispensed is a function of the distance the piston travels.

When the piston reaches the end of its stroke, the air cylinder rod retracts, the wand valve closes and the piston valve opens. As the metering piston is pulled back to its “home” position it creates a vacuum behind it into which liquid from the reservoir is drawn via a suction tube. A foot-valve on the suction tube keeps it full once it has been primed

The stroke length is mechanically set in the center section of the apparatus. A mechanical stop only allows the piston rod to travel a set distance. This distance is varied, based on the height of the joist cavity and the amount of liquid to be dispensed per cycle.

The programmable controller unit *(PCU)*

The PCU tells the air cylinder when to extend and when to retract.

The cycle time is based on how much air pressure is driving the air cylinder, the stroke length and how much back pressure is created by the dispensing nozzle. A totalizing counter on the control box counts the cycles and records the total number of cycles on the machine. A total quantity of consolidant dispensed can therefore be calculated. A countdown counter is also located on the control box. This can be set by the operator. When the applicator is activated, it will perform the number of cycles that have been input on the countdown counter and then shut off.

Description of the set-up process
The conservator determines by experiment what amount of material will be required to consolidate a given area. At the Colonial Building, trials indicated that a pre-wet of diluted resin at 1.3 L/m^2 followed by a full-strength application of 900 ml/m^2 will be sufficient to stabilize the plaster.

At the Colonial Building there is deafening between the floors. Deafening consists of a course grained plaster mix approximately 50 ml thick poured onto loose boards that are supported by slats nailed to the sides of the joists about midway between the underside of the floor boards and the upper side of the plaster and lath. The presence of this material which cannot be moved greatly restricts the potential travel of the application apparatus. The maximum possible dispense stroke was therefore set at 75 mm. By calculation the dispense volume per stroke was established at (40 ml / 25 mm) x 3 or 120 ml.

Using a 2° downward angle dispense nozzle, a triangle of application with dimensions 75 mm high and 750 mm long was created. (See Figure 5.) The distance between joists is determined. The established trajectory and width of cavity (350 mm) determined the specific treatment area. In this case the area was 0.625 m^2. The quantity of consolidant calculated for the given area was 480 ml.

The consolidant volume to be dispensed determines the number of stokes required to accomplish the desired coverage. In this case the stroke count was established at 6 strokes.

Six strokes at 75 ml will be required to deposit 480 ml of material evenly over the subject area of 0.625 m^2, effectively treating the joist cavity for a distance of 750 mm from the access location. A 180° rotation after the first 6 stroke cycles accomplishes the same objective in the opposite direction. This represents coverage of 1.5 m treated from one hole. In these ceilings with 6 m spans it was determined that 4 access holes were required in each joist cavity.

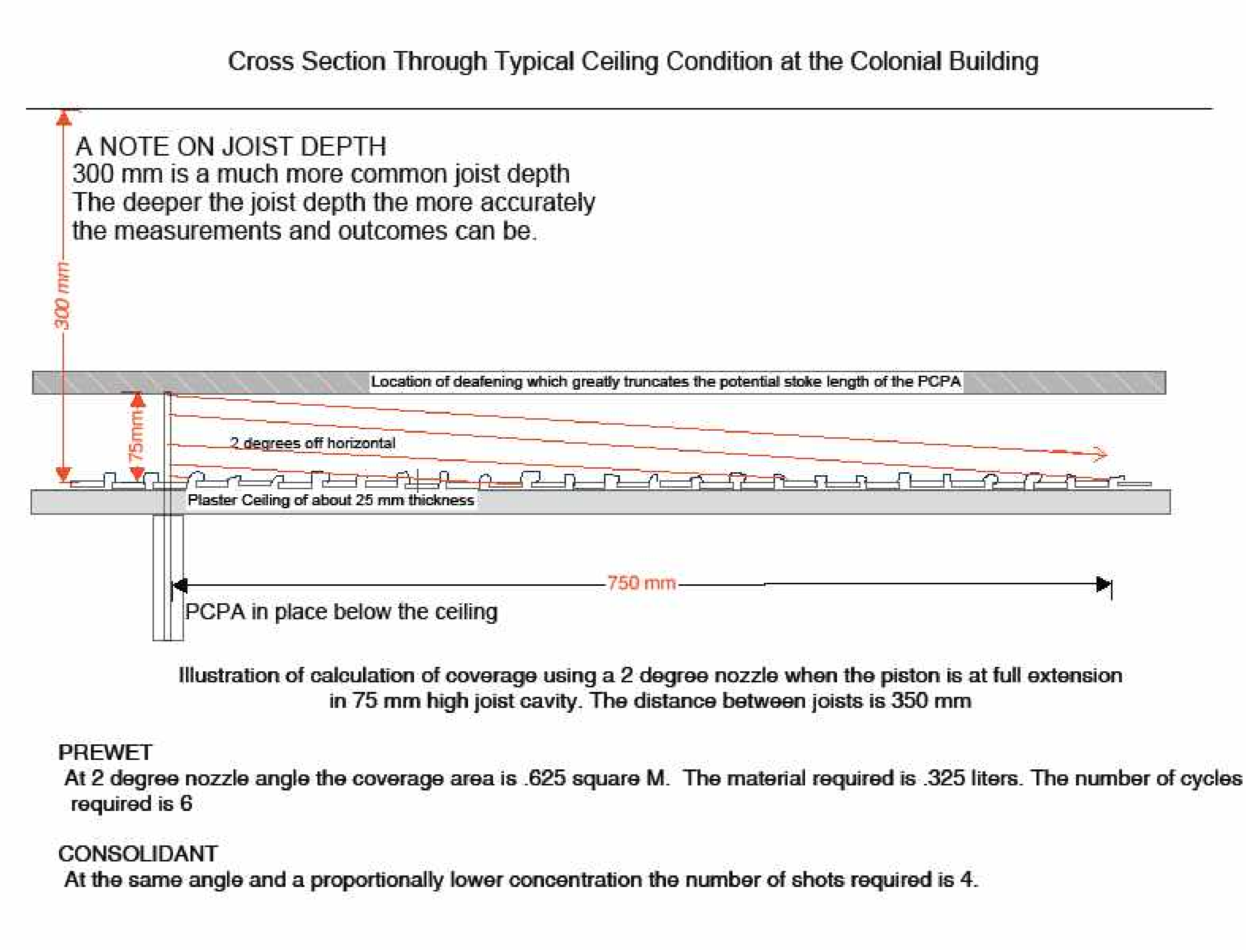

Figure 5: Cross-section of the Treatment Zone in a Joist Cavity

This technique is not universally applicable
Site conditions at the Colonial Building created a severe challenge to this new technology. Trials conducted in the attic, where it was possible to observe the distribution in full, open joist cavities using the constraints present in the deafening locations, were at first quite discouraging. The minimal application height of 75 mm meant that spray was sometimes interrupted by a particularly high lug. Occasionally, the spray head was just peeking over some of the higher lugs, constraining the spray to a smaller area than intended and not delivering consolidant to the areas beyond what looked like mountain peaks.

Ultimately a set of double-headed spray nozzles with very low dispense angles was devised. Trials using a 1.5° downward angel were successful and this was ultimately adopted as the standard for the Colonial Building work where deafening was present.

The presence of deafening in a ceiling almost precludes the usefulness of the apparatus and technique because the short stroke height limits the coverage distance so dramatically that many more holes than one would wish have to be created in the ceiling. This would not be acceptable in a ceiling with important decoration.

Most of the floor above the subject ceilings at the Colonial Building have been opened one way or another to permit the installation of mechanical equipment. In all cases without exception where floors had been opened, all the debris from the disruption of the deafening, often including the support boards, was found left on the ceiling surface. All this material had to be sought out and removed because it would have prevented any beneficial penetration of the consolidants into the plaster. In a situation where a floor could not be disturbed, this would be great cause for concern.

A future trial may involve treating alternate joist cavities. The thinking is that the span of unsupported plaster between two treated joist cavities is only 50% of the width (typically 350 mm), and that this is not too great a span for the most deteriorated plaster. This might be an important consideration in situations where known decoration would be interfered with. The cost and intervention levels would be almost halved in such a scenario. Miniaturizing the entire apparatus to achieve a wand diameter of 3 or 4 mm is also a distinct possibility.

Boroscopes and other ways of looking into cavities are available but they are not particularly useful because of the constraint the small access hole size used puts on lighting. Our best device will only allow a view of 50 cm into a cavity.

Experiments in full depth joist cavities.

Experiments were conducted in full depth joist cavities on the upper floor of the Colonial Building. Here with no deafening present and the attic floor boards removed, the entire application could be observed. In 300 mm depth joist cavities a maximum coverage of just under 5 meters was established by spraying both directions from a central application hole. This result was very promising and replicates results from a test bed created in our shops where the apparatus was developed.

Conclusion

The Colonial Building presented a severe challenge to this technology. The calculated amounts of consolidant were dispensed and had the consolidating effect but the number of holes in the ceiling required to accomplish this may be more than would be acceptable in the presence of important decoration.

The intent of this technical development is to provide an economical means of dealing with fragile plaster in historic buildings that are subject to heavy occupancy loads and where direct access to the joist cavity is not possible. The number of historic buildings that have vernacular wood lath and plaster in need of treatment far exceeds the number that are appreciated as monuments. The development of this PCPA apparatus is intended to result in a reliable tool and methodology being available for use in “ordinary” historic buildings, by normally skilled conscientious practitioners.

Acknowledgements

The authors would like to thank the Colonial Building Advisory Committee who have been working for many years to bring the renewed Colonial Building forward as one of the most

important historic structures in Newfoundland. They have been very supportive of our work there and we greatly appreciate it.

Herb Stovel and Adam Zielinski both worked at the Ontario Heritage Foundation in the 1980s and at that time introduced me to the work of Morgan Phillips and plaster conservation. For that I remain grateful.

My dear wife and partner Masumi Suzuki saw the idea for this apparatus develop as we inspected the hundreds of ceilings at Old City Hall in Toronto together. She has been a mainstay of support and encouragement throughout this and many other plaster conservation product development projects.

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Materials and Suppliers

All the resin formulations and many others not mentioned in the above paper are available from:

Historic Plaster Conservation Services Limited
26 Barrett Street
Port Hope, Ontario
L1A 1M7
(905) 885 8764

e-mail: Info@HistoricPlaster.com
Web site: www.HistoricPlaster.com

Biographies

Rod Stewart has worked in the heritage building restoration field for 35 years. He formed Historic Plaster Conservation Services (HPCS) (link to **http://www.HistoricPlaster.com**) in 1988 to pursue opportunities in the very specific field of plaster conservation. HPCS furthers the work of the late Morgan Phillips, a noted American architectural conservator. Stewart has developed practical applications for the Phillips' experimental work and has applied the technology to some significant historic buildings in Canada and the United States. His professional memberships include the Association for Preservation Technology (life member), ICOMOS Canada (former board member), the Architectural Conservancy of Ontario, and the Canadian Association of Professional Heritage Consultants (founding member).

Greg McEwan has worked in the liquid application industry for 28 years, specializing in single- and dual-component adhesives and coatings. He has been the CEO and president of Cammda Corporation for the last 15 years. His main interest is in product development — both in developing chemical formulations as well as mechanical application systems. Greg has developed a number of positive displacement devices for the simultaneous metering, mixing, and dispensing of dual-component resin systems as well as single-component metering dispensing systems for specific applications where mainstream equipment offerings are inappropriate.