

LINOSTONE: A SANDSTONE COATING PRODUCT INVESTIGATED

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¹ *Scottish Lime Centre Trust (research carried out at the University of Edinburgh, funded by Historic Scotland and supported by the British Geological Survey)*

Abstract

A year-long study was carried out to provide the first documented investigation of the sandstone coating product Linostone to understand the material characteristics, processes of ‘failure’ and to identify a means by which to remove it from sandstone buildings. Originally designed for aesthetic improvements on sandstone buildings (c.1960), Linostone has since been adapted and redesigned to repair spalling or friable sandstone masonry by incorporating an additional ‘primer coat’. The coating is a resin-based material incorporating sand and other solid components applied as a paste onto the masonry in several coats in total no more than c.2mm thick. Sand is cast onto the wet paste and joints are marked out to give the appearance of ashlar sandstone masonry. The composition and application procedure, however, is likely to have been frequently adapted in terms of composition and application procedure by individual contractors.

A block-by-block survey was carried out on a tenement building in Edinburgh both before and after the removal of a full ‘Linostone’ coating. This documentation allowed the comparison of the condition of the coating with that of the underlying masonry. Coating removal was carried out by the use of a combination of superheated steam and a solvent-based paint stripper/remover. This was found to be generally successful, but much care was needed in the removal technique.

‘Failure’ of the coating, in the form of blisters, is a common feature of Linostone and this study identified that ‘failure’ does not generally occur at the coating-sandstone interface, but within the sandstone. This therefore implies that detachment of a Linostone coating will damage, or enhance the pre-existing damage, of underlying stonework. ‘Failure’ is enhanced on face-bedded stones and at the edges of cement patches. The ability of Linostone to undergo physical change in fluctuating environmental conditions is believed to influence its detachment and blistering.

Keywords: Linostone, sandstone, Scotland, coating, face bedding, cement

1. Introduction

Scotland is well known for having suffered the ill effects of the stone cleaning boom in the second half of the 20th Century (Historic Scotland, 2007a), where inappropriate methods were used for the removal of thick black pollution crusts.

At the same time other options were being developed for improving the appearance of blackened buildings, including a sandstone coating product called Linostone. Patented between 1957 and 1960, Linostone was designed as a thin coating to replicate the appearance of new ashlar sandstone masonry. The use of Linostone, or similar products collectively referred to as ‘Linostone’ by the industry, has been widespread

throughout Central Scotland and is still in use today. Research was carried out between November 2007 and January 2009 as the first known investigation into these coating products to gain a greater understanding of their properties and applications. Observations of 'failure' of these coatings are relatively common, mainly in the form of blisters and for this reason the research aimed to understand the processes of 'failure', the effect that it has on the condition of the masonry and whether it was possible to remove a defective coating.

2. Linostone

At the time this research was undertaken, Veitchi Ltd, a Glasgow-based company, were the owners and manufacturers of the Linostone product having purchased the rights to it around 16 years earlier. The *in situ* coatings that were investigated could not be confirmed to have been applied using the official product or the official application procedure but did have the general characteristics of the official product and would have been referred to by the industry as 'Linostone', hence the use of the term in inverted commas.

The patented Linostone is composed of 42.3 parts polyvinyl acetate resin blend, 6.0 parts water, 20.7 parts lithopone (pigment), 10.3 parts talc and 20.7 parts quartz sand. The manufacturers say that Linostone can be set apart from other products by its high solid content of 65-70 *per cent*, where others are said to have 33-35 *per cent* solid content.

The stone substrate should be clean and firm prior to application of the coating. Firstly a thin primer layer of the Linostone is applied to the stone by brush or spray and then pressure sensitive tapes are placed over this in the position of the mortar joints. Once dried a second coat of Linostone mixed with c.5-10 *per cent* by weight of water is sprayed or brushed directly on top. Whilst still damp a translucent layer of sand is applied by spray or hand over the surface and then the tapes are removed. A polyvinyl acetate resin blend product referred to as Linostone Finish is then applied over the surface. The finished coating is just 1-2mm thick and has the appearance of finely jointed ashlar sandstone.

The modern Veitchi Ltd application procedure is similar although now the initial step is to treat all surfaces prior to Linostone Application with a product known as Linotol Stabiliser, an acrylic resin liquid that is designed to provide '*a microporous protective surface with a key to receive most decorative coatings*' (details from product data sheet). Two Linostone layers are still specified, although without the alteration to the water content and the use of the tapes and cast sand has not changed. No finish layer is applied unlike in the original specifications. The finished colour of the coating comes from a combination of the pigment included in the Linostone and the colour of the cast sand.

The original Linostone product is understood to have been designed for aesthetic improvements, whereas the current product is marketed as '*especially useful where spalling stonework is required to be made good*' implying that it is a physical repair product. The introduction of the Linotol Stabiliser probably saw the change in the use for the product as this would enable the coating to be applied onto more friable surfaces.

The patented Linostone (1960) was designed as a '*waterproof coating*' that '*breathes*'. In addition the patent states that '*during excessive rain [the Linostone] softens slightly and when drying out, re-hardens. This ensures that the coating is sympathetic to changing atmospheric conditions.*' When 'Linostone' coatings 'fail' they tend to do so by forming blisters indicating that the coating has pulled away from the substrate.

3. Aims and objectives of the research

A broad study was carried out looking at application variability and how the composition of the sandstone substrate may have affected the subsequent deterioration of the coating. This paper focuses on the surveys that were carried out on a case study building in central Edinburgh to understand the processes of failure of this type of coating. In addition the removal process that took place on the case study building was assessed for its suitability and success.

4. Methods for the block-by-block surveys

A four storey, mid-terrace, late nineteenth century, ashlar sandstone tenement building in central Edinburgh acted as a case study during this research. This building had a full 'Linostone' coating applied in 1988 which was in a state of deterioration and was to be removed from the full façade. Several removal methods were trialed and thin sections of the stone examined to assess the effect this has on the sandstone and if there could be any potential issues with back-diffusion of the material into the stonework. This could potentially cause further issues (this work was carried out prior to the research). The most successful method was found to be the use of the DOFF superheated steam system to remove the thickness of the coating down to a thin skin and then to apply a paint stripper/solvent with the trade name Stonehealth No. 6 to soften the coating. This was left overnight and then washed off at lower pressures with the DOFF system the following day.

A central section of the building was assessed block-by-block from a scaffold at eye level and then documented prior to removal of the coating, with a particular record of where the coating was seen to blister or 'fail'. Each course of stone was given a number (from one at ground level to 45 at cornice level) and then each block in each row was given a letter from left to right so that each block could be easily identified. Prior to the erection of the scaffold, observations were also made of water dispersal issues on the building following heavy rainfall. Following removal of the coating, the condition of the underlying stonework was then assessed to identify the level of damage to each stone, the presence of ordinary Portland cement (OPC) repairs, the bedding direction of the stone and the blocks that had been identified for replacement by the project architect. The surveys produced a set of data that could be compared qualitatively as graphic representations referred to as 'block diagrams' and quantitatively using the statistical chi squared (χ^2) method to identify whether there were any correlations between the condition of the coating and the condition of the masonry.

5. Results of the block-by-block surveys

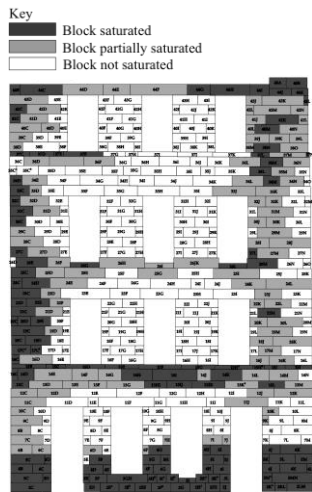


Fig. 1. Water dispersal issues

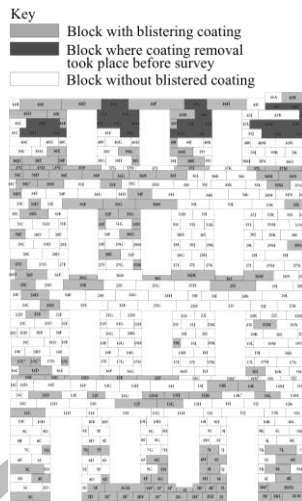


Fig. 2. Blistering coating

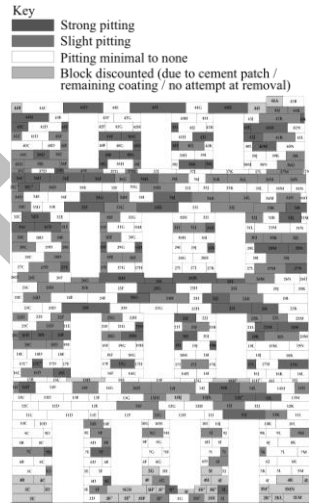


Fig. 3. Coating removal pitting

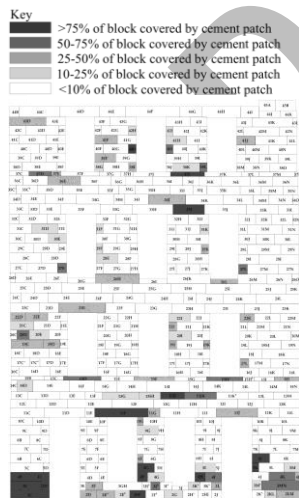


Fig. 4. Cement patches

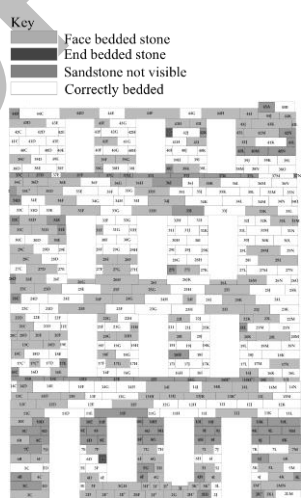


Fig. 5. Natural bedding direction

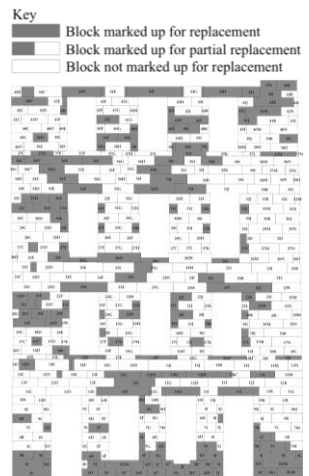


Fig. 6. Stone replacements

Figures 1-6. Block diagrams displaying the block-by-block survey results.

a. Water dispersal issues

During heavy rainfall, prior to erection of the scaffolding, the case-study building showed four main areas of enhanced water saturation; a point at the right-hand side of the gutter directly below the chimney where water appeared to be directed toward the wrong end of the gutter and was subsequently overflowing and draining down the front of the building; a point half-way down the left-hand side of the façade beside the down pipe and adjacent bay window ledge; the two string courses between the ground and first floors; and a significant rising damp issue at ground floor level. This data was not collected as part of the block-by-block surveys and could therefore not be accurately correlated with the other data sets from which block diagrams were produced, but a diagram was produced to represent the observations.

b. Blistering coating

In several places on the case study building the coating had a blistered appearance. The blisters varied from tens of centimetres in diameter down to less than one millimetre. If a small amount of pressure was applied, the majority of the blisters could be broken in a brittle manner revealing a cavity behind, either hollow or containing loose sand grains derived from the stone substrate. Coating material that had detached from the stone substrate was commonly observed to have several millimetres of sandstone still attached to its inner surface. The block diagrams for blistered coating and the observations of water saturation were compared and indicated that blistering is more likely to occur in a water saturated area.

c. Damage to the stonework caused by the coating removal technique

The apparent damage caused by the coating removal technique was recorded as; no pitting, minimal pitting, slight pitting and strong pitting. The blocks that might require replacement as a result of damage following coating removal were identified as 'slightly pitted' and those identified as 'strongly pitted' were considered to almost certainly require replacement. Sandstone in close proximity to a cement patch seemed to have a high chance of suffering from severe pitting.

470 blocks of stone were surveyed following removal of the coating and of these 243 were recorded as having no pitting or minimal pitting, 110 with slight pitting and 84 with strong pitting. 33 blocks were not assessed because either a cement patch was covering the entire block or no attempt had been made at removal because it was already clear that the stone would need replacing.

d. Cement repairs

Cement on the façade of the case-study building came in two main forms; either as re-pointing/infilling of recessed joints or as larger patches of varying size and thickness in any location. The cement observed around the edges and joints of the masonry blocks

is believed to be a method used for preparing the stone (possibly infilling mortar joints) prior to the application of the coating. This is not part of the Linostone application specification given by Veitchi Ltd., but it is a technique that was observed to be in use at the time of this research on a site where a 'Linostone' type coating was being applied.

The larger cement patches on the case-study building pre-dated the application of the coating, although by how long is not clear. The patches varied in thickness, some several centimetres thick, which indicated that cement had been used to repair stonework that was already damaged or decaying, whilst others were only a few millimetres thick and were more likely to be associated with surface preparation prior to the coating application. The condition of the cement was variable across the façade with the majority of the larger patches cracked and often fairly easily separated from the sandstone substrate by hand and the underlying stone was deteriorated and friable.

Most cement patches did not cover the entire block and observations tended to show that the coating blistered over the sandstone at the margins of the cement patches rather than overlying the cement (see figure 7).

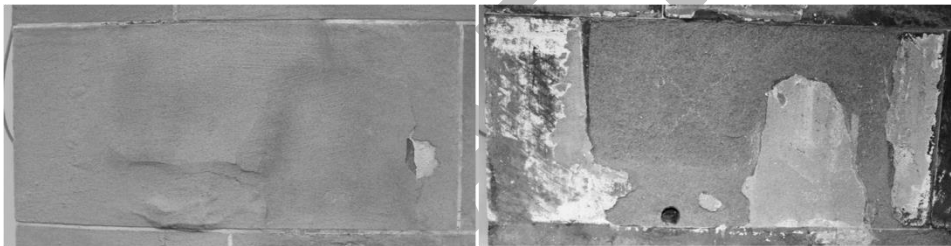


Figure 7: The same block on the case study building that showed blistering of the coating prior to removal (left) and cement patches either side of the area of blistering coating following its removal (right). A stone core was taken from the block, visible at the base of the right-hand image.

The block diagram for cement shows just the locations of cement patches covering more than ten *per cent* of a block's surface, but does not display the widespread use of cement along the joints (generally less than ten *per cent*). The notable areas of cement patching on the case-study building include a cluster at the first floor level on the left-hand side and at the base of the building; both areas identified as having high levels of water saturation following heavy rainfall.

Almost 20 *per cent* of the masonry blocks on the case-study building had a cement patch covering at least ten *per cent* of the surface area. One third of these were located on rows two to six at ground floor level (row one was not documented). Just over a quarter (27 *per cent*) of the masonry blocks adjacent to a window or door were found to have a cement patch covering more than ten *per cent* of the surface area. Only 13 *per cent* of blocks not adjacent to an opening were found to have a similar cement patch.

e. Face bedding

Sandstones have a natural bedding plane that should be placed perpendicular to the direction of maximum compression in a structure. In ashlar masonry the sandstone

should be placed with the bedding planes horizontal. However, sandstone can often be found with the bedding planes vertical and either parallel with the outer face of the building, face bedded, or perpendicular to the outer face of the building, end bedded. These stones are inherently weaker within a structure. From here on face bedded and end bedded stones, will be referred to collectively as 'incorrectly bedded', which applies to more than 40 *per cent* of the blocks. It was not possible to assess this where the coating had not been removed, where there was a large cement patch or where a dark pollution layer obscured the stone's surface; this was the case for 84 of the 470 masonry blocks. The main indicator of incorrectly bedded stones was the presence of the platy mineral mica lying parallel with the surface of the stone.

f. Stone replacement

It is standard practice on sandstone tenement buildings in Scotland to remove and replace defective masonry. The number of stone replacements that would be required could not be identified prior to removal of the coating. One significant area of damage that was already visible, however, was the corncicing at high level where there had been a loss of material. In addition, the high number of cement patches visible at ground floor level indicated that a number of replacement stones would be necessary in this location, particularly because there were also significant associated internal damp issues.

Following removal of the coating, the project architect marked up the masonry blocks that would be requiring replacement, as displayed on the block diagram. Not all of the damaged blocks were to be fully replaced, but where possible, if the damage was localised at an edge beside a stone being replaced, then this could be replaced as one.

One third (32.5 *per cent*) of the total blocks on the case study building were marked up for full replacement and a further six *per cent* for partial replacement. Many of these partial replacements were intended to be replaced with a neighbouring stone enabling replacement as a single block. Ten of the 13 lintels on the case study building were marked up for replacement. Of these, nine were found to be face bedded; the three lintels not requiring replacement were all correctly bedded.



Figures 8. & 9. The case study building prior to any work being carried out in 2008 (left) and following completion of the work in 2009 (right).

g. Chi squared (χ^2) analyses of block diagram data

Statistical analyses using the chi squared (χ^2) method were carried out between the different sets of data collected from the block-by-block surveys to identify correlations. The factors compared against one another were blistered coating, the higher levels of pitting of the sandstone following removal, cement patches, natural bedding direction and stone replacements. Null hypotheses and alternative hypotheses were set up for each statistical analysis. In each case the Null Hypothesis is that there is no relationship between the two factors studied and the Alternative is therefore that a statistical relationship exists.

For all data sets the threshold value of χ^2 for one degree of freedom at the 5% level is 3.84 and for 0.1% level is 10.83.

Table 1: Results of the chi squared (χ^2) analyses

	Slightly or strongly pitted	Cement patches (covering a surface area over 10% of the block)	Incorrect bedding direction	Full stone replacement	Partial stone replacement
Blistering coating	18.2	11.7	22.3	35.0	29.9
Slightly or strongly pitted		19.0	41.2	65.0	51.5
Cement patches (covering a surface area over 10% of the block)			29.8	179.6	154.7
Incorrect bedding direction				84.4	79.2

Based on the threshold values, as given above, these are all statistically significant results and all of the Null Hypotheses can be rejected and all of the Alternative

Hypotheses must be accepted. The results therefore show, with 99.9% confidence, that each of the relationships shown in the table occurred with frequencies that cannot be explained by random chance. These factors are therefore all positively related.

6. Discussion and conclusions

The information collected from the block-by-block surveys of the case study building were found to be highly significant as clear correlations between the sets of data were demonstrated. The observations of water dispersal issues also contributed to an understanding of the deterioration of the 'Linostone' coating in many key areas.

The case study building acted as a good example of a visually typical 'Linostone' type coating with the standard blister features of a deteriorating coating. The presence of cement patches on the case study building, believed to pre-date the coating, are an indication that there was already a level of stone deterioration on this façade prior to application of the coating. The survey results showed that a high level of incorrectly bedded stones were present on the case study building adding an inherent weakness to the masonry. This may well be due to the lack of a distinct bedding structure, however this stone type still had a direction of preferential mineral orientation due to the manner in which it was formed geologically. The strong correlation between cement patches and incorrectly bedded stones indicates that these incorrectly bedded stones were weak in relation to correctly bedded stones within the building.

The condition of the individual blocks of stone on the case study building prior to application of the coating was unknown. The use of cement as a repair material is likely to have provided a temporary solution but ultimately to have exacerbated any previous problems, namely the inherent issues associated with face bedding. The strong presence of cement patching in the area of rising damp indicates that this has been a long-term problem, which had most likely been compounded by these repairs. Ease of access for applying the cement may have influenced the amount of repairs carried out here. The same could be true for the slightly above average number of applications of cement around window and door openings as they are easier to access and therefore easier to repair. It is likely that many, if not all, of the numerous cement patches at high level were applied in a single phase because access would be difficult without a scaffold.

It is unknown why the decision was taken to apply the coating material, but it is possible that the high level of cement patches was considered unsightly and a 'Linostone' type coating provided a solution for improving the appearance of the building. Additional cement that is believed to have been used to prepare the surface of the stone prior to application of the coating material will have added to the decay issues that are related to the use of impermeable mortars. It is not known how common this practice is when applying this type of coating (it is not a practice promoted by the manufacturers), but this could certainly affect the condition of the underlying sandstone. Although Linostone is believed to have a low level of breathability, it would still limit the movement of liquid water and water vapour into and out of the stone. The stonework is likely to have remained damp for long periods following heavy rainfall because the moisture would not be able to easily evaporate from the surface due to the coating barrier, and this would not have been possible at all where cement was present. The

coating on the case study building is considered to have been applied using the modern Veitchi Ltd procedure including a Linotol Stabiliser layer or similar product. This is a thin layer which in thin section does not appear to penetrate past the outer layer of mineral grains, but has a strong bond with them.

Linostone is said to soften when wet (this was demonstrated in simple laboratory tests) and also was found to increase in flexibility with increasing temperature. If these adaptations occur where the stone is in a sound state then it may well have no effect. If however, the stone is either in a deteriorated state or has an inherent weakness, such as face bedding, then the adaptation of the coating material could well add additional stress onto the stone's surface and allow it to pull away from the stone substrate. The strong bond between the coating and the substrate means that the coating would pull away with some of the substrate attached which, as identified, could be several millimeters of the stone's outer surface. Hall & Hoff (2002) illustrate exactly this, that if the bond between a surface finish and the underlying substrate is stronger than the backing surface alone, then this will lead to failure of that backing surface not the applied material. This ties in well with the observation that blistering coating is correlated with the presence of a cement patch, because the sandstone at the margins of the cement patch are likely to be in a state of deterioration. It could therefore be argued that the failure of the coating increased the deterioration of the sandstone.

The coating removal method of a combination of a paint stripper/solvent and superheated steam (DOFF) appeared to be generally successful. The DOFF system appeared to be able to take the coating down to a thin white layer without reaching the stonework in most places, allowing the solvent to then work through the remaining thin layer of coating before being washed off at lower pressure with the DOFF system. Where the stonework was in a good condition the removal was generally successful with only a low level of surface pitting, possibly as a result of the nozzle for the superheated steam being too close to the substrate. A stone that is already in an enhanced state of decay will have a low tolerance to pressure due to the breakdown of its binding components and any attempt to remove the coating is likely to result in damage. This was particularly the case, and shown to correlate, in areas where the coating had blistered and at the margins of cement patches. Each block was individually treated, however, the latter may be due to higher pressures being used where it appeared that the substrate of a block was stable (over the cement patch) but that when the hose moved to the non-cement coated part of a block the pressure was too high and cut through the outer few millimeters of the stone. The paint stripper/solvent does not work below temperatures of 5°C, which may have impacted on its success in this case because it was used in lower temperatures at some stages of the work.

A large proportion of the stonework on the case-study building is being replaced following removal of the coating due to its poor condition which is related to the factors as laid out above. This information gives an insight into the areas of the highest levels of deterioration but does also include blocks that may have cracked or suffered mechanical damage, which were not dealt with in this study.

One aim of this study was to create an understanding of what the appearance of the coating might say about the state of the underlying substrate. The statistical analyses

could therefore be used as a basis for mathematical modeling to predict the probable level of repair on buildings with similar features of coating deterioration.

We cannot say that 'Linostone' type coatings necessarily cause the initial deterioration of the stonework, but that where they fail they will enhance any underlying stone deterioration due to the strong bond between them and the sandstone substrate.

This study leads to the question; in what circumstance could you effectively use Linostone on a sandstone building? If the stonework is sound then there would be no need to coat it, and if it was in a state of decay then this type of coating may be a temporary fix but ultimately is likely to exacerbate the deterioration. Many such methods have been tried over the past century for preserving the structure of our built heritage, but the end result is that they do not seem to stand the test of time and may result in more harm than good (Caroe & Caroe, 1984).

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